REPORT OF SURVEY CONDUCTED AT

LOCKHEED MARTIN
ELECTRONICS & MISSILES

ORLANDO, FL

APRIL 1995

BEST MANUFACTURING PRACTICES

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Center of Excellence for Best Manufacturing Practices

PREFACE

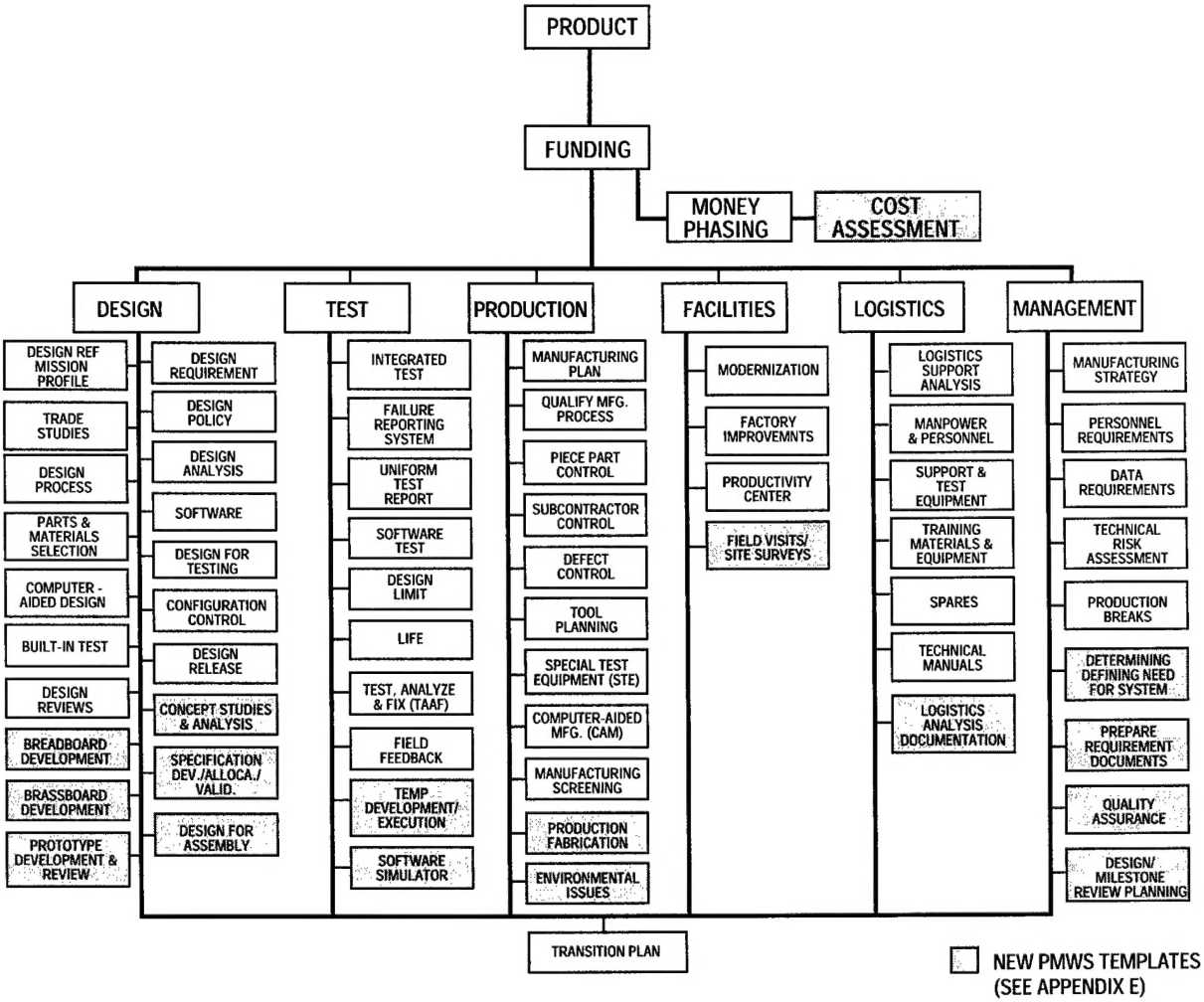
During the week of 24 April 1995, a Best Manufacturing Practices (BMP) survey was conducted at Lockheed Martin Electronics and Missiles (E&M). E&M is headquartered in Orlando, FL with additional sites in Ocala, FL; Pike County, AL; Goldsboro, NC; and other U.S. and international locations. Part of the Lockheed Martin Electronics Sector located in Bethesda, MD, E&M maintains three primary product mission areas and the technologies key to these missions such as electro-optics, millimeter wave radar, image and signal processing, miniaturized and large scale ICs, and multi-sensor fusion. The application of these technologies produced over $1B in sales last year to Lockheed Martin Electronics and Missiles from customers which include all U.S. military services and foreign nations approved by the U.S. Department of State. Over 5,000 employees occupy E&M facilities that encompass more than 3,000,000 square feet.

Two Lockheed Martin programs have produced significant results and provided pivotal support for the company's 1995 ISO 9001 accreditation, the first for a U.S. aerospace company of its size. These programs are its internal Best Practices program and its Integrated Product Teams effort. The Best Practices Program is an integrated program in benchmarking and continuous improvement that provides Lockheed Martin with a set of focused practices and metrics that specifies initiatives, plans, and implementation milestones. The Integrated Product Teams represent another outgrowth of the company's dedication to excellence and continuous improvement. These self-directed teams apply the *concepts* behind the internal Best Practices program.

BMP surveys are conducted to identify best practices in one of the critical path templates of the Department of Defense (DOD) 4245.7-M, "Transition from Development to Production." This document provides the basis for BMP surveys that concentrate on areas of design, test, production, facilities, logistics, and management. Practices in these areas and other areas of interest are presented, discussed, reviewed, and documented by a team of government engineers who are invited by the company to evaluate the company's policies, practices, and strategies. Only non-proprietary practices selected by the company are reviewed. In addition to the company's best practices, the BMP survey team also reviews potential industry-wide problems that can be referred to one of the Navy's Manufacturing Technology Centers of Excellence. The results of the BMP surveys are entered into a database for dissemination through a central computer network. The actual exchange of detailed data is between companies at their discretion.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrial base. Improving the use of existing technology, promoting the introduction of enhanced technologies, and providing a non-competitive means to address common problems are critical elements in achieving that goal. This report on Lockheed Martin Electronics and Missiles will provide you with information you can use for benchmarking and is part of the national technology transfer effort to enhance the competitiveness of the U.S. industrial base.

"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"



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SECTION 1

EXECUTIVE SUMMARY

1.1 BACKGROUND

Lockheed Martin Electronics and Missiles (E&M) is headquartered in Orlando, FL with additional sites in Ocala, FL; Pike County, AL; Goldsboro, NC; and other U.S. and international locations. Part of the Lockheed Martin Electronics Sector located in Bethesda, MD, E&M maintains three primary product mission areas – Missile Systems, Fire Control Systems, and Advanced Systems. Varied technologies are key to these missions such as electro-optics, millimeter wave radar, image and signal processing, miniaturized and large scale ICs, and multi-sensor fusion. The application of these technologies produced over $1B in sales last year to Lockheed Martin Electronics and Missiles from customers which include all U.S. military services and foreign nations approved by the U.S. Department of State. Over 5000 employees occupy E&M facilities that encompass more than 3,000,000 square feet.

The Best Manufacturing Practices (BMP) program frequently sees companies with focused programs in benchmarking and continuous improvement. It is less common, however, to find a company that has integrated the two into its *own* "Best Practices" program as did Lockheed Martin Electronics and Missiles in Orlando. The BMP program recently conducted a survey at Lockheed Martin and determined that the company's internal Best Practices program was an outstanding feature that influenced all aspects of its business. In addition, that program received substantial support for implementation through its Integrated Product Teams (IPTs) whose objectives incorporated many Total Quality Management (TQM) initiatives. These two Lockheed Martin programs produced significant results and provided pivotal support for the company's 1995 ISO 9001 accreditation, the first for a U.S. aerospace company of its size.

Development of its internal Best Practices program is a response by Lockheed Martin to many changes and significant events, some dating to 1985. Although in-house continuous improvement efforts are not unique, this program is significant in how Lockheed Martin benchmarked outside customers, industry, and its own improvement initiatives and integrated them into a concentrated set of focused practices and metrics. It specifies initiatives, plans, and implementation milestones. This program is strongly supported by a high level executive advocate for each Best Practice area and represents the best of Lockheed Martin's efforts to adapt to a rapidly changing defense marketplace.

If the Best Practices Program is a highly effective process at Lockheed Martin, the company's IPTs constitute the critical element to its successful implementation. Another outgrowth of the company's dedication to excellence and continuous improvement, these self-directed teams apply the *concepts* behind the Best Practices program. All IPT members are stakeholders in setting performance goals, solving problems, and helping guide management decisions. They help distribute the workload, facilitate employee empowerment, and foster ownership, all key ingredients to productive TQM – and Best Practices – performance.

Like many defense-related industries and companies, Lockheed Martin Electronics and Missiles is adapting to changes in the market environment. Continually benchmarking itself against the internal and external "best," integrating what it learns in a closed-loop process, and applying conscientious efforts to produce high-quality products for its customer, Lockheed Martin Electronics and Missiles successfully produces practices such as in this report that are among the best in industry and government.

1.2 BEST PRACTICES

The BMP survey team found the following best practices at Lockheed Martin Electronics and Missiles.

1.3 INFORMATION

The following information items were highlighted by the BMP survey team at Lockheed Martin Electronics and Missiles.

1.4 ACTIVITY POINT OF CONTACT

For further information on any item in this report, please contact:

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SECTION 2

BEST PRACTICES

2.1 DESIGN

DESIGN POLICY

Simultaneous Development

Simultaneous Development at Lockheed Martin Electronics and Missiles is an integrated approach to program management that strongly resembles traditional concurrent engineering or integrated product/process development (IPPD). However, Simultaneous Development begins at the proposal phase and continues through production. It also is pervasive throughout Lockheed Martin's product development teams instead of being piloted by select projects.

Historically, Lockheed Martin used the traditional sequential military product development cycle that consisted of Concept Exploration, Development, Full Scale Engineering Development, Low Rate Initial Production, and Production. With this system, the company experienced typically-associated problems including difficulty in transitioning to production, high first-unit cost, supportability problems, and a lack of IPPD. Recognizing that this approach was not yielding any competitive advantage, Lockheed Martin adopted Simultaneous Development.

Simultaneous Development is comprehensively implemented at Lockheed Martin and several issues contribute to its success. The core members of the integrated product development groups are first teamed in the project's proposal. This facilitates bringing various disciplines together early in the process to achieve a common understanding of the program objectives. Another critical aspect to Lockheed Martin's successful use of Simultaneous Development is bringing its vendors in with the development team up front. Production tooling is accomplished early in the subcontractors' facilities to ensure project buy-in at all levels.

As equally important as its vendor base, the customers are involved early in the development. Lockheed Martin explains the approach to customers and continues to involve them during all stages of development. This effort ensures continuous feedback into the project. Lockheed Martin also believes in a strong up-front manufacturing involvement. To this end, they validate all essential production processes in Phase I, and strive for six sigma capability on all critical processes by Phase II. This guarantees only mature processes are utilized, and that variability reduction is accomplished before the first unit is delivered.

Applying this Simultaneous Development philosophy has resulted in benefits such as reduced schedule/cost risk, lower manpower requirements, lower overall program costs, higher quality products, and increased flexibility. It has greatly increased Lockheed Martin's competitive position in the marketplace. The philosophy of Simultaneous Development is extensive throughout Lockheed Martin, enjoys strong management commitment, and its results are significant.

PARTS AND MATERIAL SELECTION

Requirements Management

Lockheed Martin successfully applies requirements management through closely-related initiatives. Obsolescence Management combines manufacturer information and technology assessments with various tools to predict when components and products will become obsolete. Commercial Technology Insertion addresses replacing military-specified parts with commercial products, obsolete units as well as new designs. A third requirements management initiative, Enhanced Built-In-Test, is aimed at eliminating Intermediate Level Maintenance.

Obsolescence Management provides risk information on electronic component technologies to help designers determine whether the components they select will meet the life cycle development and cost-of-ownership requirements of the design. Obsolescence Management uses the Document Information and Control System for displaying on-line data. This on-line obsolescence information helps the engineer select current technology for product designs and also provides source data used by procurement and product assurance personnel. The system also furnishes descriptive data for standardization, parts control, and part status.

In the second initiative, Lockheed Martin is focusing Commercial Technology Insertion's initial effort on microcircuits. A commercial component is any nonmilitary part – ceramic or plastic – including telecommunication, computer, medical, automotive, industrial grade, or other devices. The Commercial Technology Insertion program provides a comprehensive plan for the selection, application, and procurement of reliable, low-cost commercial components. Current emphasis is on replacing ceramic components with plastic. Moisture-induced and temperature cycling failures are two major long-term reliability considerations for plastic components. These considerations are being analyzed against

various product requirements. Potential cost saving opportunities and return on investments for plastic over ceramic components can exceed a 75 to 1 ratio.

In a related effort, Enhanced Built-In-Test teams have designed and developed extremely high density ASICs to meet system requirements. Digital ASICs with greater than 250,000 logic gates have been designed. In some ASICs, internal clock speeds of 1 GHz have been utilized. These electronic densities and speeds have driven creative approaches to component, module, and system built-in-test. This Enhanced Built-In-Test functionality centers around the IEEE-1149.1 Joint Test Action Group bus. At the component level, E&M has a patent pending on the self-test technique Fabilus™ for digital ASICs. This technique allows the ASIC to perform self test and output a go/no-go code to the 1149.1 bus. The heart of the module and system-level Enhanced Built-In-Test is an inexpensive, patent-pending ASIC known as the Digital Test and Maintenance ASIC. This ASIC controls the bus and facilitates system-level-at-speed testing. Two other ASICs, the Analog Test and Maintenance ASIC and the temp-sense ASIC, add the ability to handle analog signals and temperature considerations to the 1149.1 bus. Full implementation of the Enhanced Built-In-Test concept eliminates factor test equipment for electronics and limits field test equipment to a PC with an off-the-shelf 1149.1interface card. The test software is highly reusable, and the software is used from engineering development through field support. A high percentage of the test software is also reusable from system to system.

CONFIGURATION CONTROL

Product Definition System

The Product Definition System (PDS) is an on-line, integrated management system for all product definition data and processes at Lockheed Martin Electronics and Missiles. Comprised of two subsystems, Product Manager (PM) and Concurrent Engineering Manager (CEM), PDS is integrated with the Aerospace Planning Execution Control System (APECS) to provide on-line access to the latest information. This, in turn, enhances product and process cost visibility, encourages concurrent engineering, incorporates producibility parameters, and provides traceability.

The PM supplies document management, product structure, and change management capabilities. Document management includes digital data engineering models, drawings, and analysis data. PM also provides interfaces to material requirements management, logistics, business information, and other systems in the PDS architecture (Figure 2-1). Lockheed Martin's customers, suppliers, and partners have PM view capability of

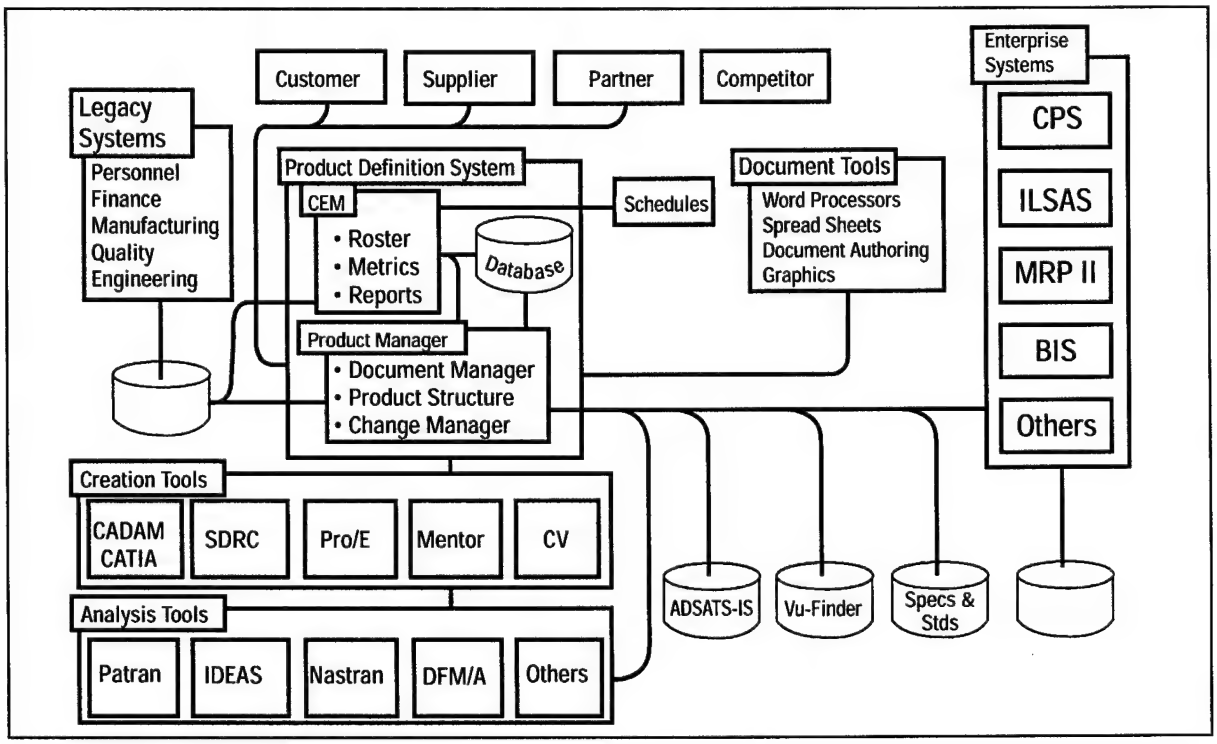


FIGURE 2-1. PDS ARCHITECTURE

information that applies to their respective interests. CEM provides database access to reports, resource information, metric information and schedule activity. The combination of the PM and CEM subsystems allows user access to personnel, finance, manufacturing, quality, and other legacy systems.

PDS features document and drawing red-lining, revision and version control, electronic mail integration, and workflow management. Data and information management is accomplished through a distributed vault concept. Documents are checked in and checked out in accordance to various access privileges. The privileges are assigned to either individuals or groups based on their functions and need to know.

The PDS-APECS interface forms a tight coupling between the engineering and manufacturing build cycle. PDS contains As-Design and As-Planned Bills-of-Material (BOMs) for each product. The As-Planned BOM is used to generate the initial Manufacturing BOM that resides in APECS. The Manufacturing BOM is then modified as appropriate and is used to kit, fabricate, test, and inspect the product. The manufacturing process results in an APECS Build History database which provides As-Built data in PDS. The PDS-APECS interfaced system provides a means to readily analyze the variations between the engineering BOM, manufacturing BOM, and the actual final product.

DESIGN FOR ASSEMBLY

Key Characteristics and Variability Reduction

Lockheed Martin Electronics and Missiles has adopted an approach called Key Characteristics and Variability Reduction to its quoting, design, and manufacturing processes as part of the company's continuous improvement efforts. This approach (Figure 2-2) has enabled Lockheed Martin to translate critical customer requirements into detailed specifications, facilitating separating "critical few" from "trivial many" product features.

Lockheed Martin used to follow the classical approach of defining the system requirements, conducting a trade-off analysis, assigning component requirements, and detailing the resultant specifications. This did not support the company focusing efforts on the few critical attributes, while allowing standard practice to accommodate the nonessentials of the design.

Acknowledging that it would be extremely difficult to conduct Variability Reduction techniques on all the variables of all the products/processes involved, Lockheed Martin identified the relatively few high-level critical features of any design. Each of these features, in turn, could have many crucial components which contribute to the overall criticality, but the analysis greatly reduced the field of consideration.

Once identified, variability reduction and the resulting statistical tracking is applied to those critical features. Process capability studies are conducted and a trade-off analysis made to determine which machines/processes can achieve the required key characteristics.

One result of using this methodology was the invention of a variability reduction flag being incorporated into Lockheed Martin's drawing packages and procurement documentation. This flag indicates to both subcontractors and their own shop floors which geometric features are absolute must-haves and which features they can apply the knowledge of their trade to modify for ease of manufacture. This effort provides a

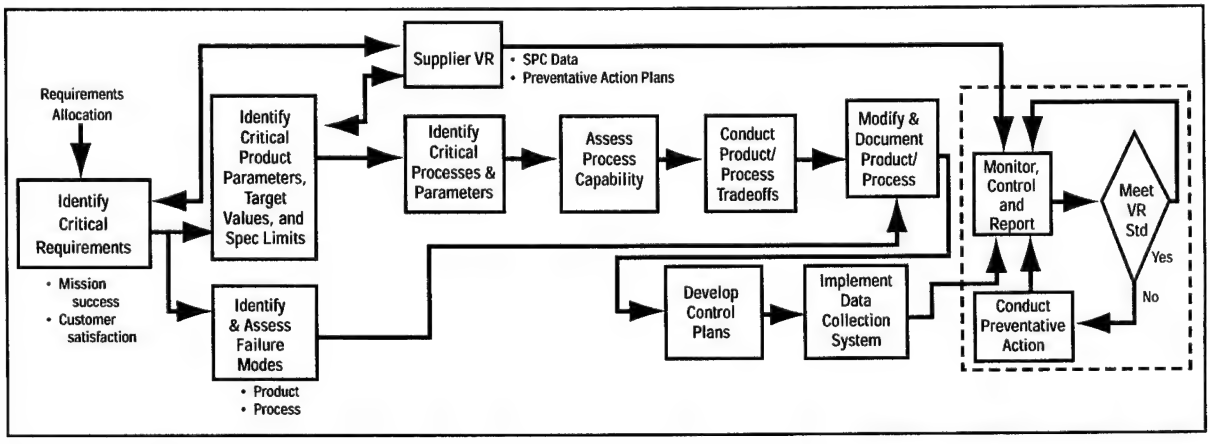


FIGURE 2-2. KEY CHARACTERISTICS/VARIABILITY REDUCTION APPROACH

substantial benefit to the design process by allowing the original equipment manufacturer to provide input up front, as well as greatly reducing the habitual Engineering Change Proposals that follow any new design.

Lockheed Martin is currently filtering this approach – along with the DFMA methodology – down into its vendor base, thereby demonstrating the commitment to continuous improvement.

Design for Assembly Process

Lockheed Martin has identified and effected a key methodology to successfully implement the principles of concurrent engineering. This Design for Manufacture/Assembly (DFMA) approach ensures the proper balance between making components simple to *produce* as well as making them simple to *assemble* (Figure 2-3). The net result is a robust design that is more cost effective to manufacture.

The company previously applied the concurrent engineering philosophy using a traditional design review process. It determined that a formal event called a DFMA workshop was needed to ensure design-for-assembly and design-for-producibility considerations were addressed. After careful analysis, Lockheed Martin selected the Boothroyd Dewhurst, Inc. software to help achieve this objective. To demonstrate commitment, Lockheed Martin established a policy that DFMA be included in all programs.

Lockheed Martin then embarked on a training program that taught the principles of DFMA and the specifics of the Boothroyd Dewhurst, Inc. tools to the product teams. The various disciplines represented on the team were taught the methodology, and the teams were required to use this approach in a real-world application. The teams first established the as-is baseline model of their products, then brainstormed and iterated solutions to simplify the assembly. Finally, at the end of the training, each team presented its analysis to management.

The critical ingredients to this successful Lockheed Martin approach include mandating the requirement, training personnel, providing each team a real-world case study, and involving management. The resulting synergy of this approach has helped the company achieve the desired goals of simplifying both the design and the processes necessary to manufacture and assemble the design. Lockheed Martin has been able to significantly reduce the BOMs required to manufacture components, and over the life cycle of the many systems it produces, these component-level savings are substantial.

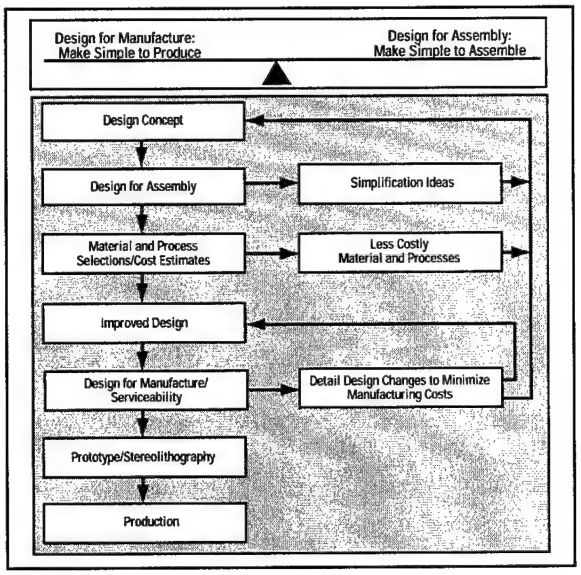


FIGURE 2-3. BALANCE DESIGN FOR MANUFACTURE AND DESIGN FOR ASSEMBLY

2.2 PRODUCTION

MANUFACTURING PLAN

Manufacturing Process Development

Lockheed Martin recently instituted a change in how new or revised Manufacturing Processes (MPs) are introduced in the manufacturing arena. This process provides a methodology for a systematic approach to process development. Prior to making this change, Lockheed Martin followed the traditional approach of new process introduction where product/process matching was not normally performed, interim process reviews were not conducted, nor were estimated standards/cycle times developed concurrently with the process (Figure 2-4).

Recognizing a need for change, personnel at Lockheed Martin have developed and tested an approach that is disciplined and systematic for instituting a new or revised MP. Key characteristics of the process and product are cross-checked; process capabilities are analyzed; process validation is performed before turning the process over to production; and steps are added to ensure constant process reviews (Figure 2-5).

Since instituting this change, Lockheed Martin personnel maintain that the success of introducing new or revised MPs has greatly increased while driving down process developmental costs and enhancing schedule performance.

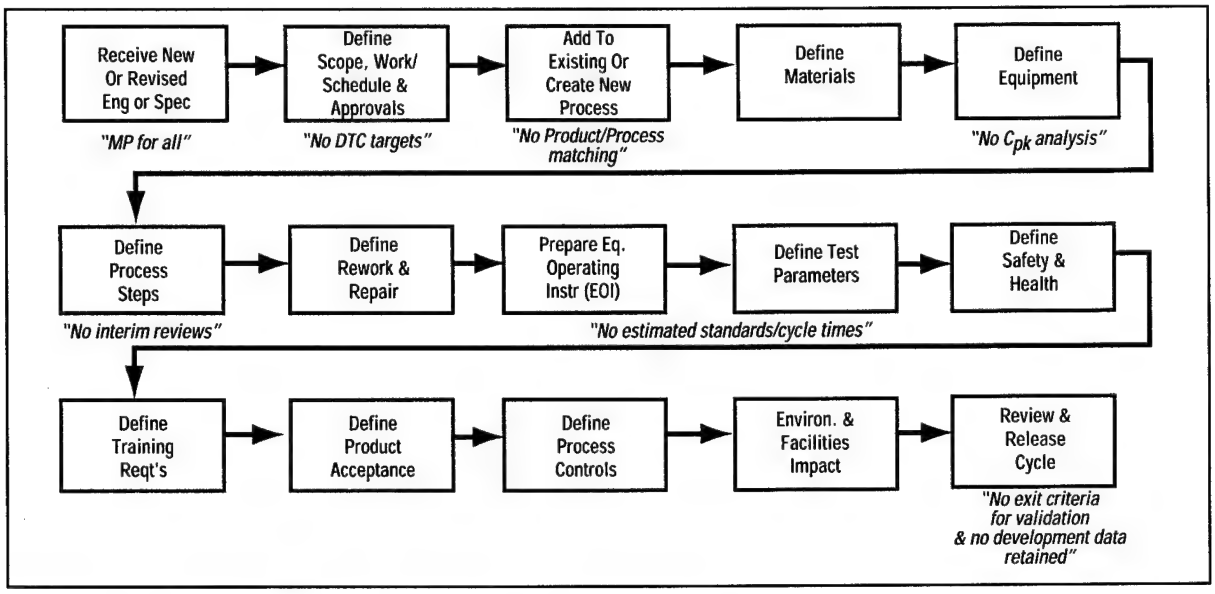


FIGURE 2-4. PROCESS DEVELOPMENT - OLD APPROACH

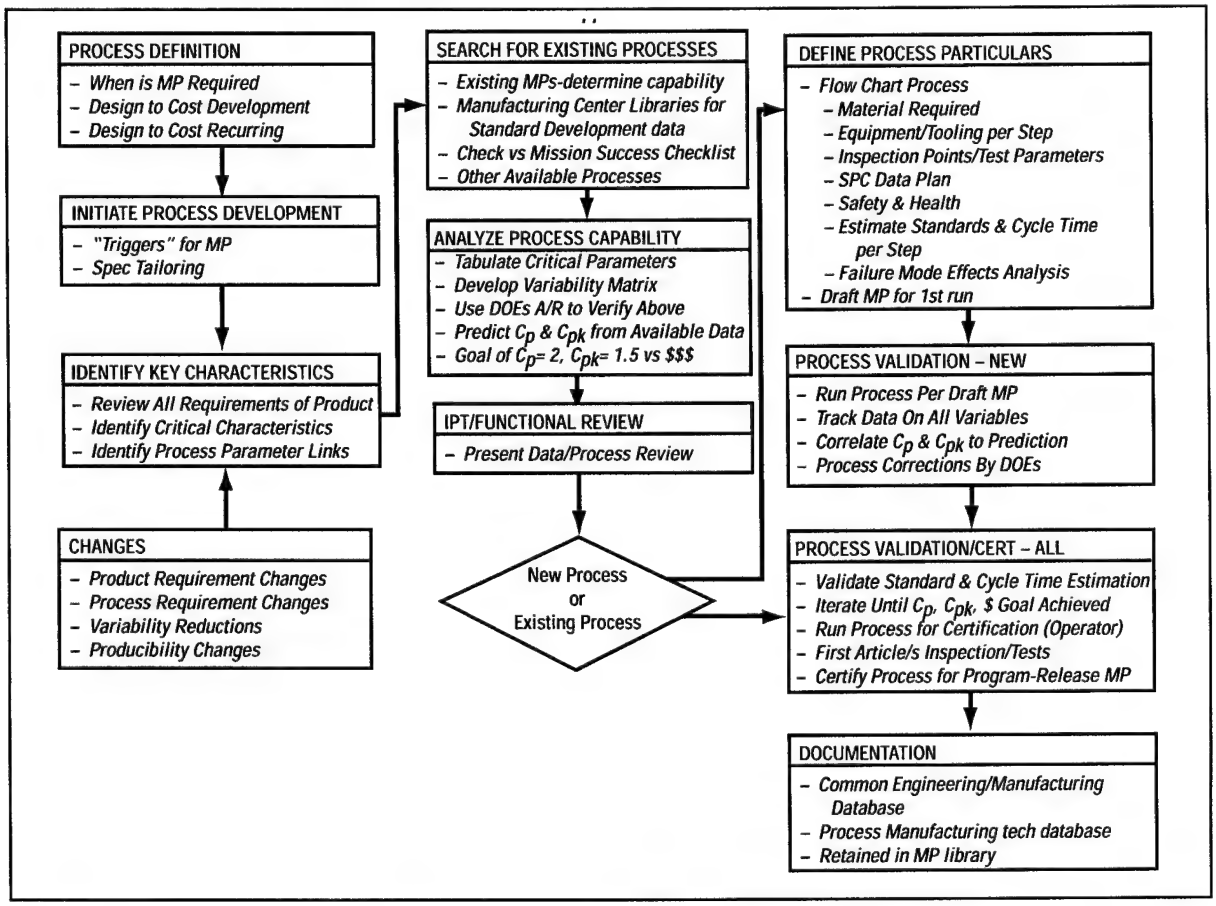


FIGURE 2-5. SYSTEMATIC APPROACH TO PROCESS DEVELOPMENT - NEW APPROACH

Manufacturing Systems

In response to a need to reduce the associated total costs of information systems, Lockheed Martin developed APECS, a three-tiered architectural system to integrate the Shop Floor Control Systems, Manufacturing Information Systems, Process and Test Documentation System, and Material Requirements Planning System. The previous system did not have the capability to integrate the multiple components into a single system. Consequently, Lockheed Martin advanced the development of a new system to support:

- reducing end-user costs of information systems to a reduced manufacturing base;
- modifying production operations' systems to support business change to more research and development programs;
- improving end-user productivity; and
- supporting strategic corporate goal to create an integrated enterprise.

APECS, which Lockheed Martin started developing in the early 1990s, consists of a Factory Control and Tracking System (FACTS) to replace multiple existing Shop Floor Control Systems, Routing and Process Instruction Development (RAPID) to manage Process and Test Documentation, Simplified Material and Requirements Tracking (SMART) to perform Material Requirement Planning, and a Manufacturing Reporting System (MRS) to provide Manufacturing Information. FACTS and RAPID are in use, and SMART and MRS will be implemented. Implementation of the entire integrated system will be completed before 2000. The integration hardware for the Distributed APECS Architecture (Figure 2-6) consists of UNIX servers and Windows workstations and are tied together by a LAN.

This system will increase user efficiency, provide a common reporting tool for manufacturing, provide a scalable capabilities changing business, promote standardization across business functions, and place information analysis in hands of the user.

SPECIAL TEST EQUIPMENT

Product and Line Test Validation

Lockheed Martin uses Process Validation to meet the requirements of test environments, customer demands, concept and design review baselines, and design standards. Process Validation ensures the accuracy, repeatability, and reliability of the process through analysis and independent verification.

Process Validation includes simulation and modeling, a test station validation plan, and a production readiness assessment. Simulation and modeling encompasses circuit simulation and analysis, mechanical simulation and dynamic analysis, verification of tests performed, input power and signal verification, test station and UUT damage protection, software walkthrough of critical modules, correlation and repeatability, UUT failure mode analysis, and self test capability. Production Readiness Assessment is under development and will ultimately be conducted by an

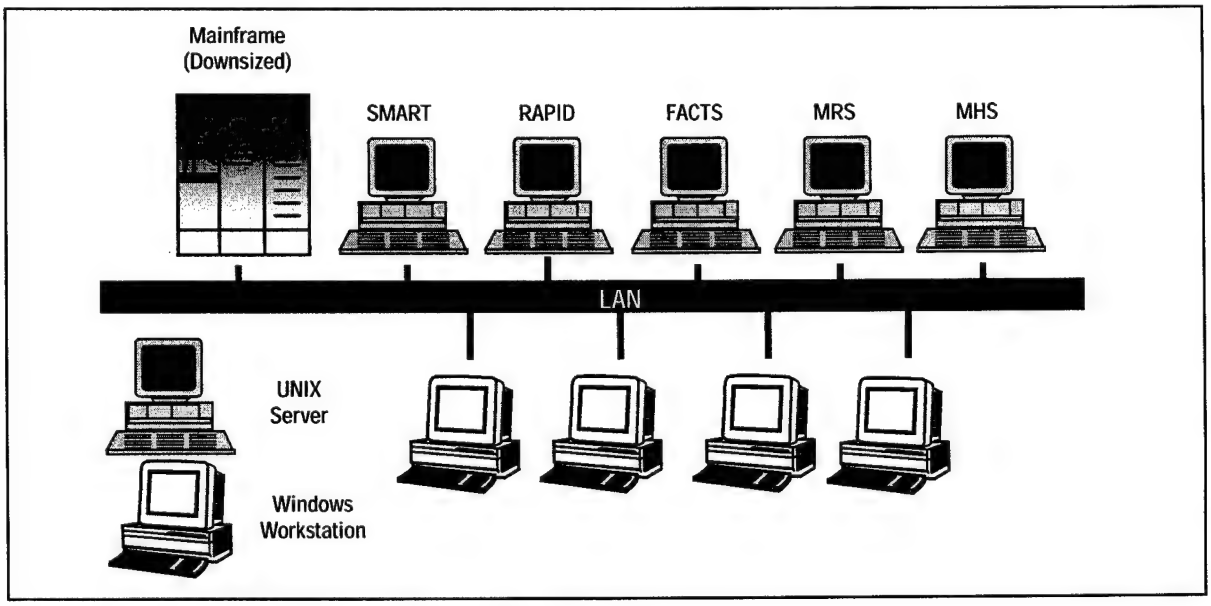


FIGURE 2-6. DISTRIBUTED APECS ARCHITECTURE

independent team consisting of Quality Engineer, Manufacturing Engineer, Industrial Engineer and Customer. Production Readiness Assessment consists of assessing the Factory and Depot Test Equipment, Production Tooling, Test Procedures, Calibration Procedures, Preventive Maintenance Plans, Equipment Operating Instructions, UUT Testability and Producibility, and Production Flow.

This Process Validation approach presents benefits such as a reduction in test station debug time, faster ramp-up to full rate production, lower production support costs, verification of production line readiness, early availability of process variability data, efficient production test flow, verification of product testability and producibility and achievement of test equipment accuracy levels of ten to one.

Because all process validation methods are integrated, unnecessary tests are eliminated, numbers of test equipments required are reduced, production bottlenecks are identified early in the manufacturing cycle, and production costs are minimized.

ENVIRONMENTAL ISSUES

Environmental Practices

Lockheed Martin Electronics and Missiles designed the Pollution Prevention and Environmental Practices program to reduce pollution control costs and to comply with increasing pollution regulations. Lockheed Martin's Pollution Prevention and Environmental Practices constitute a strong environmental effort. The corporate philosophy of 100% compliance 100% of the time, and commitment of top management and employees have a significant impact on pollution prevention and control. As a part of the pollution prevention strategy, Lockheed implemented corporate-mandated programs, incorporated customer-specified programs, adapted existing cultural practices to requirements, re-engineered chemical inventory management, and created employee awareness. Lockheed also successfully participated in the following EPA voluntary programs:

- green light relamping over a million square feet which yielded cost savings of over $25K per year;
- energy conservation projects such as computer control of air conditioning and improved chiller cleaning and maintenance; and
- 33/50 toxics reduction.

Lockheed Martin has recently completed the design of the Chemical Inventory Management Program with procedures that require environmental, safety, and health approval and tracking numbers prior to order; re-engineer order/receiving and distribution systems; interface existing business software to an environmental information database; and create a state-of-the-art, cradle-to-grave tracking system.

2.3 FACILITIES

MODERNIZATION

Transition to Ocala

In mid-1993, Lockheed Martin decided to move a major program from Orlando to Ocala, approximately 70 miles away. This move would involve not only moving the program, but also establishing new facilities, moving equipment, training new personnel, and recertifying equipment. The time constraint on this move was driven by program requirements for production deliveries to begin in five months.

To facilitate the move, a transition team, representing four main support groups, was established to build the new organization at the new site. This team developed detailed plans and timelines to ensure that all aspects of the undertaking were considered. Performance Management Teams which included hourly workers at each site were established to ensure that no details were overlooked. Once the plans were finalized, various sub-teams were established to execute the plans. Daily meetings were held between task leaders and team leaders to quickly identify any problems and take corrective action immediately.

This major program/facilities relocation began at the end of October 1993 and was completed with full-scale production beginning at the new facility in February 1994. And the cost required was less than the original projection.

2.4 LOGISTICS

SUPPORT AND TEST EQUIPMENT

Property Management

The Lockheed Martin Electronics and Missiles property management group has implemented a computerized Property Control System (PCS) for controlling all company and government assets. The Property Management group is the sole interface to the resident government property administrator and plant clearance officer for all Lockheed Martin property. This group addresses property procedures, identification and classification, storage and movement, inventory, audits, and contract closeout. The activity also oversees equipment acquisition, receiving, maintenance, and subcontractor property control.

PCS contains mandatory fields for items such as Federal Acquisition Regulation requirements. PCS also contains a module and process that does not allow equipment

calibration unless it is first identified and tagged and entered into the PCS database. The system is instrumental in maintaining custodial control for equipment with over 2200 custodians identified for over 78,000 line items of property. PCS has a master menu that contains sub-menus for maintenance, inquiry, report request, mass data change, calibration, and family code assignment. The on-line system allows inquires by account, classes, custodian, user, and account validation, and also tracks equipment on loan.

New procedures for large programs with substantial quantities of property are evaluated by a full-time person assigned to the program. This property management representative resides in the program area and performs all property management functions for the program. This person is also assigned as the custodian for all the program's property.

The PCS and new procedures combine to provide better control of joint venture property, frees program personnel to perform their primary tasks, and allows faster processing of property transactions.

TRAINING MATERIALS AND EQUIPMENT

Computer-Based Education

Lockheed Martin Electronics and Missiles applied a unique solution to the recurring training requirements of large manufacturing facilities. The company developed a system called Computer-Based Education by identifying repetitive training requirements that could be taught on a computer-based platform instead of in the traditional classroom environment. These courses include hazardous material training, safety, sling and hoist operations, and clean room procedures.

The courses were modified for a self-paced computer environment and placed on Lockheed Martin's existing computer system. This allowed all employees access to the training through either the LAN or modem. This system greatly increased accessibility for Lockheed Martin's remote locations and personnel on travel. It also reduced the cost of each course since once developed, there were no additional classroom, instructor, or presentation costs.

This approach is best applied to repetitive, mandatory training and allows Lockheed Martin to ensure the latest and most current information is correctly presented. Employees are notified of pending training requirements and can take each course at their own convenience. Training statistics are easily obtained and managed. Most importantly, Lockheed Martin has structured each course to require a 100% correct score to complete the session. All problem areas are immediately presented to the student for subsequent retesting until all the learning objectives are met.

As a result of using the Computer-Based Education system, Lockheed Martin has seen the average time required for an employee to complete a course decrease from 45 minutes (when the system was first implemented) to the current 24 minutes. Additionally, student usage has grown from almost 8000 hours to over 30,000 hours annually.

The training, financial, and administrative benefits of this type of system clearly make it a system with far-reaching potential. The use of existing computer systems and LANs demonstrate Lockheed Martin's commitment to finding innovative solutions to industry-wide problems.

2.5 MANAGEMENT

MANUFACTURING STRATEGY

Best Practices

Lockheed Martin Electronics and Missiles has instituted a company-wide Best Practices program that focuses on the quality of the process as well as the product. The approach provides broad coverage of representative Department of Defense and other customer thrusts such as the Army's Contractor Performance Certification Program $(CP)^2$, the Air Force's Manufacturing Development Initiative, ISO 9000, and Agile Manufacturing, and incorporates them into 12 Best Practices (Table 2-1). Each of the Best Practices is clearly defined (Table 2-2) and supported by a vice-president-level, executive advocate and a management implementation team.

Lockheed Martin's Best Practices program was a response to major forces such as changes in the defense market, downsizing, and decreased funding levels for defense-related programs. The multifaceted objective of the program is to increase market share and profitability by continually benchmarking customer, industry, and Electronics and Missiles improvement initiatives; integrating them into a coherent set of focused practices and metrics; coordinating the implementation plan for these practices; publishing and marketing the Best Practices; and continuously measuring, assessing and reevaluating.

Under the leadership of the executive advocate for each Best Practice area, the implementation team identifies initiatives and develops plans and milestones for implementation. The plans cover 18 months, include key elements, identify responsible individuals, and specify metrics. Each of the Best Practice areas designates a continuing series of "Silver Bullets," each an initiative targeted for that practice for completion in the current year across all active programs.

The Best Practices Program at Lockheed Martin is a highly effective, company-wide process that enables the company to operate proactively within the environment of rapid and constant change in the defense marketplace. The

TABLE 2-1. BEST PRACTICES SELECTION APPROACH

	E&M Best Practices	Customer/Industry Acquisition and Development Thrust															
		1. MDI (Air Force)	2. $(CP)^2$ (Army)	3. MIL Prime	4. Acquisition Reform	5. Navy BP/ Willoughby	6. R&M 2000	7. ISO 9000	8. Lean Aircraft Initiative	9. Agile Manu-facturing	10. DFA DFM DFS	11. SE!	12. Price to Win	13. EPI/ESC	14. Design Assurance	15. EIA Mfg White Paper	16. Re-engineering
Cost as a design requirement	✔	✔	✔			✔	✔	*			✔		✔				✔
Supplier partnerships	✔	✔	✔		✔	✔	✔	*	✔	✔			✔		✔		✔
Embedded quality systems	✔	✔	✔			✔	✔	✔	✔			✔			✔		✔
Requirements management	✔	✔	✔	✔	✔	✔	✔				✔	✔	✔			✔	✔
Customer focus	✔		✔	✔	✔				✔				✔				✔
Product and line validation	✔	✔				✔										✔	✔
Risk management	✔	✔	✔		✔	✔	✔	*	✔			✔	✔			✔	✔
Simultaneous development	✔	✔				✔	✔		✔			✔	✔	✔		✔	
Teams/skills	✔				✔	✔	✔			✔		✔			✔		
Key characteristics	✔	✔	✔			✔	✔									✔	
Cost management	✔					✔	✔		✔						✔	✔	✔
Variability reduction	✔	✔	✔			✔	✔	*								✔	

*ISO 9000 as a Quality System Standard supports these but does not give details for their implementation.

TABLE 2-2. BEST PRACTICES DEFINED

Cost as a Design Requirement

Cost is as important to the design as performance. It is managed as a design metric, like weight. Design/process alternatives are traded to achieve lowest cost that meets the requirements.

Simultaneous Development

Parallel design of product, process, tooling, test equipment and support equipment is accomplished by empowered, trained, multidisciplined teams in concert with customer and supplier.

Requirements Management

Standards, specifications, and contract requirements are tailored with customer to meet program needs at minimum cost. Off-the-shelf, modular design, reuse, and standard parts usage is promoted.

Cost Management

Cost management ensures that processes and cost are continually assessed; issues managed pre-emptively, opportunities for improvement identified, implemented, and reported.

Risk Management

Factors which could reasonably result in not attaining cost, performance or schedule are identified, assessed, and abated.

Embedded Quality Systems

The system elements and processes are the source of product and service quality.

Key Characteristics

Design characteristics which most influence performance, supportability and cost are matched against production process capability.

Product and Line Validation

Assure the processes provide the expected product within planned capabilities and consistent with program requirements.

Supplier Partnerships

Suppliers are integrated early into IPD activities to capitalize on their product and process expertise. Use of same key suppliers across programs is encouraged.

Teaming & Skills

Capitalize upon the knowledge and skills of our people through teaming and acknowledge their contributions via incentives, rewards and recognition.

Customer Focus

Customer treated as a partner with open access. Programs sensitive and responsive to all customer needs.

Variability Reduction

Variability of critical product and process parameters are monitored, controlled, reported on, and improved to meet a process capability (C_{pk}) of at least 1.5.

program increases credibility of proposals, is effective in opening new markets, proliferates the processes and tools, and is updated annually to meet quality, cost, schedule, and performance commitments.

Compliant Audit System

Lockheed Martin Electronics and Missiles developed a Compliance Audit System as a result of a high level of audit deficiencies found by a government audit in 1985. This internal auditing mechanism was designed to check for compliance on all internal and external deliverables.

The system is well documented and is driven by procedures and its own set of guidelines and audit checklist. Measurement criteria include effective corrective action, environmental and safety, nonconforming hardware, documentation, procedures, shelf life, tool calibration and certification, facilities, property management, material handling, training and certification, and discipline. The system uses a highly visible green, yellow, and red rating system to indicate the level of compliance. Green indicates isolated incidents that do not create concern for product quality or safety; yellow denotes "minor noncompliance" that does not affect deliverable product or safety; and red alerts a "major noncompliance" that may affect delivery of a defective product, safety, or improper application of processes.

Audits are conducted throughout the Lockheed Martin facility where deliverable products are produced at scheduled times for any measurement criteria selected, and results are posted utilizing the green, yellow, red rating system. Audit deficiencies are reported, corrective actions are recorded, transactions are entered into a database, and weekly reports are filed with top management, all performed by a single person.

Critical components in this successful system have been the commitment from top management, auditor independence, top management visibility of the issues, timeliness of the responses, and immediate and effective corrective action by the actionee. This internal auditing system has contributed to the sharp reduction in external audit deficiencies from over 200 in 1985 to near zero in 1995.

Six Pillars of Character

Ethics at Lockheed Martin Electronics and Missiles is accorded priority above profit and ranked with Mission Success as an essential and overarching principle of the company's philosophy. Lockheed Martin's ethics program is a well-defined code of ethics and standards of conduct. It is administered at Lockheed Martin by a director-level ethics representative, as well as an ombudsman who reports directly to the president. The program is dedicated to ensuring that the company does the right thing and places a high priority on confidentiality.

Ethics awareness training is conducted annually for all employees. The training stresses the following six pillars of character employees should exhibit:

- *Trustworthiness*–honesty, integrity, promise-keeping, and loyalty
- *Respect* – autonomy, privacy, dignity, courtesy, tolerance, acceptance
- *Responsibility* – accountability, pursuit of excellence
- *Caring* – compassion, consideration, giving, sharing, kindness, loving
- *Justice and Fairness*–procedural fairness, impartiality, consistency, equity, equality, due process
- *Civic Virtue and Citizenship*–law abiding, community service, protection of environment.

This training also teaches awareness of rationalization pitfalls which allow a person to view his or her actions as ethical when most others would disagree. The program promotes ethical work behavior and the use of values. The goal of the program is to promote a business climate wherein all employees truly believe that to improve the working environment through ethical conduct benefits the employees and the company.

Integrated Product Teams

Integrated Product Teams (IPTs) represent a new way of doing business at Lockheed Martin Electronics and Missiles and involve both customers and suppliers. The IPT concept integrates TQM initiatives such as high performance work groups, people empowerment, quality of work life, culture change, concurrent engineering, design-to-cost and schedule, continuous process improvement, and customer and supplier involvement. Fostering ownership at the appropriate levels, facilitating empowerment efforts, and better distributing the workload are principal objectives of the IPT concept. Other objectives include moving decisions down the organization, making all personnel stakeholders, allocating metrics, building in all requirements, and organizing for communications.

Implementation of IPTs at Lockheed Martin has been facilitated in several areas. For example, team members are physically collocated and organized based on the project Work Breakdown Structure. Appropriate training is also provided for all members. Clear roles and responsibilities are established; concise program management plans are developed; and daily meetings are conducted and attended by DPRO and supplier representatives. Most importantly, senior management is supported and committed to the IPT concept.

Programs using IPTs have experienced dramatic improvements in cost, schedule, and performance over traditionally-structured programs. Other benefits include total "management-in-the-sunshine" with customers and upper management, elimination of redundant activities, and work done in parallel – not in series.

Lockheed Martin learned several lessons from this approach including requiring more team responsibility for cost control; ensuring better training for team leaders; and acknowledging that up-front costs are high but are recovered later. Future IPT initiatives will address improving the middle management commitment to IPTs and breaking down functional barriers, including IPT implementation costs in proposals.

Mission Success

Mission Success is a guiding principle for Lockheed Martin Electronics and Missiles. It has evolved as a core value and is a well-defined, closed-loop, "super" process. The Mission Success process includes key components within which the company's 12 Best Practices and TQM standards are embedded such as:

- providing required tools for integrated product development;
- selecting qualified employees with adequate training;
- developing error free designs;
- using approved parts and materials;
- using current manufacturing process plans;
- ensuring adequate test equipment and manufacturing facilities;
- working only to correct procedures;
- maintaining rigorous configuration and inventory control;
- implementing corrective actions;
- using independent verification and validation tests;
- using qualification tests that do not miss requirements;
- conducting reviews that concentrate on designs, test plans, and test results; and,
- applying system tests that assure design and workmanship are error free.

The Mission Success process is implemented through top-down commitment and individual responsibility at all levels. Program execution responsibility for each program is focused through the Mission Area Vice-President (under whom the program resides) to the Program Director and the IPT. Process ownership for Mission Success is concentrated through the Technical Operations Vice-President and the Mission Area Technical Director to the IPT. This approach ensures process consistency and discipline throughout the company, with sensitivity and responsiveness to the requirements of individual programs.

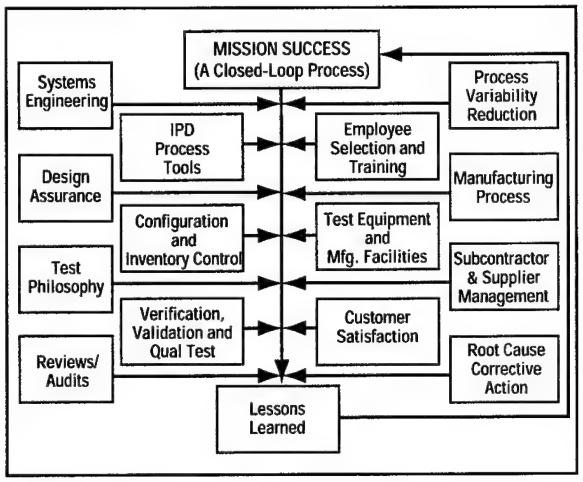


FIGURE 2-7. MISSION SUCCESS: THE INGREDIENTS

The Mission Success process is composed of a number of important subprocesses (Figure 2-7). One critical process is Design Assurance, an example of Lockheed Martin's proactive quality thrusts. Design Assurance uses a team approach to verify design solutions or identify design problems requiring attention. The key process components are to develop and teach the design standard, and follow up with timely, off-program reviews with technical experts. The reviews are held in an informal setting with emphasis on addressing and resolving problems, and subcontractors and key suppliers are actively involved. The process has been well received as evidenced by feedback rating the process excellent to outstanding in identifying problems and providing a good return on time and funds. Another effective element of the Mission Success process is the corporate lessons-learned database which is accessible through a home page on the Internet. This captures key aspects of learning that can be used to adjust and improve the process, as well as to avoid traps.

Mission Success as a process has been responsible for a highly successful record of flight and firing tests. On the five current key missile and smart munitions programs, the overall rate of successful flight and firing tests in nearly 500 attempts is 95% and is continuously improving. During the first quarter of 1995, the success rate for tests in all major programs (22 firings) at Lockheed Martin Electronics and Missiles was 100%.

PERSONNEL REQUIREMENTS

Teaming and Skills

Teaming is an integral part of the Lockheed Martin Electronics and Missiles operating culture. This teaming philosophy, internal to Lockheed Martin as well as with customers, subcontractors and suppliers, is supported at the executive level throughout the bid, proposal, design, development, manufacturing, and test and evaluation phases of most major programs and functions.

The company has established a structured team process, helped teams establish metrics, and emphasized team focus on problem resolution and process improvement. This effective and efficient use of multi disciplinary teams has active participation from nearly 75% of the company employees.

Not only a standard within Lockheed Martin, the teaming concept also provides the basis for considerable external efforts. These programs include promoting long-term associations with subcontractors and suppliers, participating in education and training with industry programs instituted by the military services, and supporting learning assignments for military personnel who work in-house at Lockheed Martin on industry programs.

Lockheed Martin is successfully transitioning to a team-based environment, supported by a strong corporate culture. The company has determined that it is well on its way to establishing a team-based working environment and company culture.

Flexible Work Force

To improve its competitive posture, the Lockheed Martin Electronics and Missiles facility in Pike County, Alabama implemented a flexible work force that would help assure the company's success in future competitions.

Lockheed Martin identified a number of actions including the need to ease and revise job classifications and include new skill requirements. Development of a cross-training program in all areas was also required. A system to track and evaluate employees' abilities and performance had to be developed. Local control and flexibility to work within established policies as well as the authority to develop local procedures would be necessary. The question of compensation to reflect the increased responsibilities and skills was also a consideration. Other decisions were required on the correct team approach, employees benefits, and the degree of participative management. And finally, training in teaming concepts had to be initiated for buy-in from the work force.

Production personnel underwent enhanced training that effectively pre-qualified them for employment. This training program was co-developed with the state of Alabama and represented a critical key to its implementation. All production functions were covered by a single job description -- receiving, stock keeping, shipping, material handling, transportation expediting, kiting, handling, assembly, painting, test, quality inspection and contract data management. Personnel were certified for multiple jobs and work assignments were based on work requirements, not job codes. Through the use of performance management teams, greater employee involvement was achieved with full implementation of operator verification philosophy.

All support functions were also included in one job description and personnel attended the same training as production employees. Support personnel addressed daily operations and supervision of the production line and were trained to perform touch labor tasks to support requirements. Responsibility, accountability, and decision-making were allowed and encouraged at the team level.

Electronics and Missiles has achieved significant benefits from the implementation of this practice. Final inspection yield was 100%, and in-process yield was 98.6%. The performance management team rework rate was .2%. There was no scrap, and the overtime rate was 4.5% and lost time was .6%. Initial manufacturing cost underrun was significant. And finally, the enhanced operator verification program has almost eliminated all manufacturing defects.

QUALITY ASSURANCE

Embedded Quality Systems

As the result of a government audit in 1985, Lockheed Martin Electronics and Missiles developed a TQM plan that has evolved into today's Embedded Quality Systems Plan. This plan focuses on those system elements and processes required to provide assurance that products and services meet the requirements of the customer. The program has been very successful and since 1989, there have been no government audit deficiencies.

Lockheed Martin previously had the typical hidden factory where products were reworked to meet the requirements, and problems causing the non-conformances were never addressed other than with band-aid style quick fixes. Quality was inspected-in instead of Lockheed Martin developing quality processes, resulting in millions of dollars worth of scrap. The 1985 audit identified deficiencies that served to alert Lockheed Martin that action must be taken to correct the situation immediately. A number of actions were implemented including establishment of Performance Management Teams, in-house as well as supplier application of statistical process control, and a strong compliance audit function.

The key elements of the Embedded Quality Systems Plan address those areas highlighted during the audit and include:

- achieving ISO 9001 registration;
- implementing Production Process Validation;
- developing and implementing a system audit program;
- establishing a Preventive Action Board;
- achieving Software Engineering Institute Level 3 certification; and,
- developing Best Practices Guidelines.

ISO 9001 certification was received in December 1994. The assessment, performed by BSI-QA, gave Lockheed Martin Electronics and Missiles international registration and allowed the company to compete worldwide. This certification has prompted Lockheed Martin to take an innovative look at processes and practices instead of the MIL-Q-9858A way.

The Production Process Validation (PPV) changes the role of the inspectors from checking hardware to monitoring processes. The manufacturing operator is responsible for hardware quality. The keys to PPV are SPC training, gauges and tools, matched and coordinated acceptance tools, pinup fixtures, and use of SPC data output from coordinate measuring machines. The inspectors monitor the manufacturing processes instead of functioning as end-of-the-line inspectors -- they are now part of the corrective action process. The inspectors audit the SPC stations for process control. The actual hardware inspection is only performed on a sample basis. The lessons learned in the implementation of PPV show that the operation must be a continuous sequence or have repeated process operations for multiple part numbers; the size of the area must be manageable; defined inspection plans and requirements must exist; a strong Performance Management Team must be in place; a corrective action system must be established; and SPC must be used to control the processes. Every area where PPV was implemented has shown an increase in the quality level.

Design Assurance

Lockheed Martin Electronics and Missiles has implemented a unique, three-part preemptive methodology discipline to ensure quality design of its products. Because it is difficult to correct less-than-optimal designs already produced, Lockheed Martin maintains that applying the preemptive discipline maximizes quality designs.

In 1987, Lockheed Martin acknowledged that improved methods and techniques in building products positively affect quality, and began to employ an enhanced methodology to build quality into the design process. Unique to the design assurance program was the focused, integrated approach to preempting problems. Emphasis was on establishing good design methods based on well-established standards and practices to consistently reflect well-researched and current lessons learned. Design assurance personnel were involved full time, had good working knowledge of the design communities' capabilities and techniques, and were well versed in program requirements, schedules, and problems. Also unique to the process was the detailed design assurance reviews held regularly at the working level.

Key elements to the design assurance process include continually generating and/or updating the theory-rich engineering practice manuals, comprehensive training of the design standards throughout the design engineering community, and the systematic approach to follow-up with thoroughly prepared review teams to ensure that standards are met.

Design assurance has proven a guiding effort to a better design process, more efficient reviews, and a focal point for lessons learned. The performance of design assurance personnel is measured by program (project) personnel with a single criteria – release of a quality design the first time. The effectiveness rating has been excellent to outstanding. Early avoidance of potential design defects has provided major cost avoidances.

Contractor Performance Certification Program

Lockheed Martin Electronics and Missiles established a goal to achieve $(CP)^2$ certification following a very successful 1989 government audit. $(CP)^2$ is an Army Materiel Command effort that recognizes contractors that consistently deliver quality products, apply process controls, use preventive and proactive audit procedures, and continuously demonstrate aggressive efforts to improve quality. The Army Materiel Command developed the $(CP)^2$ program in response to the need for change and to address industry concerns on quality and government in-plant quality assurance activities, and excessive government involvement in daily operations.

$(CP)^2$ is based on four areas of evaluation including management's commitment to total quality environment, compliance to quality system requirements (MIL-Q-9858A), implementation of SPC program in-house and at suppliers' facilities, and continuous improvement as measured by agreed-to metrics. Lockheed Martin developed a systematic approach to integrate all elements of quality into its total operation. Almost immediately, the major programs and operations at the company began seeing benefits from these newly formulated quality assurance initiatives. The company's high level of quality performance was recognized in May 1990

when Lockheed Martin Electronics and Missiles became the first company to participate in the Contractor Performance Certification Program of the Army Missile Command and the Army Armament Munitions and Chemical Command. It also became the first Army Missile Command contractor to have all production programs in an entire facility in the program.

The mission quality initiatives employed by Lockheed Martin have not only solidified its $(CP)^2$ certification position since 1990, but have continued to produce millions of dollars in savings in areas of rework, scrap, corrective action requests, request for waivers/deviations, and actions as a result of Product Quality Defects Requests. For example, rework has been reduced by approximately 12% per year and scrap reduced by approximately 10% per year for the last 7 years; corrective action requests have been reduced from 224 in 1988 to near zero since 1991; request for waivers have been reduced from 70 in 1988 to a quantity of only two recorded in 1994; and Product Quality Defects Requests have gone from 446 in 1986 to zero since 1991.

Performance Management Teams

Lockheed Martin Electronics and Missiles Production Operations adopted the concept of Performance Management Teams (PMTs) in 1985 to continuously improve the quality and reliability of the company's products and services, reduce cost and cycle times, enhance productivity and ensure schedule compliance to maximize customer satisfaction.

PMTs require a change in culture and total workforce commitment, and quality is designated as the top priority. Team performance is measured at the team level and achievements are recognized through rewards. Teams are comprised of a normal work group from areas such as manufacturing engineering, industrial engineering, production planning, quality engineering, technical operations, procurement, and safety. Where appropriate, customers also are members of the team.

The focus of the PMT process is the team's work area and responsibilities, similar to the "company within a company" concept. Team leaders are designated and support groups are made an integral and active part of the team. Teams meet once per week, review performance metrics, identify action items to improve product and services quality, and develop improvements to enhance overall efficiency. Participation is mandatory and is a major part of the Lockheed Martin performance appraisal process. Nine metrics have been established at the production floor level to include quality yield, rework, scrap, audit result, cost performance, schedule/cycle time, lost time/overtime, customer satisfaction, and action items which could have a positive impact on product service quality and reliability, cost performance, productivity, safety, schedule delivery, cycle time, or customer satisfaction.

PMT recognition is based on a reward system comprised of elements such as *Team of the Month* and *Team of the Year* designations which include an award breakfast, plaque and pins, write-ups in the in-house publication, and Teamwork Counts Suggestion Program.

The benefits of PMTs are well documented. Lockheed Martin Electronics and Missiles has had no negative government audit findings for over six years. The company was U.S. Army Missile Command Contractor Performance Certified in 1990 and ISO 9001 certified in 1994. Production scrap and rework has been reduced over 70% resulting in production budget underruns. Total program cycle time has been reduced by an average of 36% on major Lockheed Martin systems, and there has been mission success on all programs.

Metric Development Process

Lockheed Martin Electronics and Missiles recognized that to completely adopt the principles of TQM and continuous improvement, it needed to develop a way to evaluate the work of non-production employees/teams in areas such as engineering, finance, human resources, and other support roles. The Metric Development Process (MDP) was designed to measure team-based efforts which optimize quality, customer satisfaction, and continuous improvement of performance.

MDP is comprised of four phases:

1. ***Mission Development*** where products and services are identified and matched with customers, and mission statements are developed.
2. ***Metric Refinement*** during which the critical parameters to achieve the mission statement are categorized; the measurement methodology is developed; and the data necessary to establish the baseline is collected.
3. ***Validation*** where metric quality is verified and final management concurrence is obtained, and goals are negotiated and established with management.
4. ***Assessment*** where metrics are monitored to ensure continuous improvement.

The most important phase is Metric Refinement during which at least one measurement is identified for quality, customer satisfaction, cost, schedule, productivity, professional development, process improvements, and lost time/overtime. These metrics are meaningful to the customer, drive the team to continuously improve, show trends and

are clearly defined, are consistent, show a cause and effect relationship with the Mission Statement, and are timely, economical, and feasible to collect. It is also at this stage where data is aggregated and disseminated in summary reports.

The MDP puts a premium on quality, customer satisfaction, and the continuous improvement of overall team performance. This is best achieved if the customer focus is key, the Mission Statement is carefully developed, measurement takes place where improvement has value, and metric review and modification is ongoing.

Lockheed Martin Electronics and Missiles cited numerous benefits derived from the metric development process such as improved customer satisfaction, greater inventory accuracy, better documentation compliance, increased equipment uptime, and more timely critical preventive maintenance.

SECTION 3

INFORMATION

3.1 DESIGN

COMPUTER-AIDED DESIGN

Accessible Design Tools

Lockheed Martin Electronics and Missiles' mechanical design, analysis, and manufacturing functions place a strong emphasis on three-dimensional modeling as the basis for product and process definition. The mechanical environment is in transition from an IBM mainframe system to UNIX-based design tools. The mainframe system still handles legacy data while new designs are using distributed client/server workstations.

The UNIX system uses high-end HP-700 series workstations running ProEngineer solid models for both mechanical and manufacturing designs. ProPDM software manages the complex relationships between models. Other capabilities include in-house developed wire-harness design software, neutral format data, stereolithography apparatus interfaces, Boothroyd-Dewhurst Inc.'s design for manufacturing/design for manual assembly software, three-dimensional tolerance analysis, SILMA coordinate measuring machine programming, DENEB NC simulation software, NASTRAN and DYTRAN finite element modeling, and M/VISION material property and classification databases.

The migration to the distributed environment is yielding lower cost of operation, higher quality designs, better system response, higher productivity and more advanced functionality.

3.2 TEST

INTEGRATED TEST

Test Philosophy

In an attempt to achieve high quality, reliable products at affordable cost, Lockheed Martin Electronics and Missiles recently developed a test philosophy where every product delivered meets all customer requirements; failures are identified and repaired at the lowest level of assembly; testing is automated for maximum efficiency; and the test process is continually improved. This test philosophy has been applied to the areas of in-process testing, stress screening, acceptance testing, and the improvement program.

In the in-process testing effort, testing is conducted at all levels of assembly until the success rate warrants test elimination. Components are screened to ensure that only good material is allowed on the manufacturing floor. Testing is automated, where feasible, to reduce test time, and the number of different test systems is minimized. In stress screening, Lockheed Martin is attempting to induce failure of manufacturing defects before an assembly is delivered by subjecting it to thermal cycling, thermal shock, vibration, and testing for specification compliance. The company is using U.S. Air Force and Navy Environmental Stress Screening Guidelines (R&M 2000, NAVMAT P-9492). In acceptance testing, the goal is to effectively meet customer requirements by validating all equipment and procedures and procedure traceability to requirements, apply configuration management to all test procedures and equipment, control the change process, and automate testing when possible. Finally, in the improvement program, Lockheed Martin is continuously reviewing test data for failure trends to remove root causes, improve quality, reduce cost, and react to trends before failure occurs. The test process is periodically reviewed for improvement to remove tests with a high success rate, reduce test time, and improve tests to eliminate failure at next level of assembly.

3.3 PRODUCTION

MANUFACTURING PLAN

Rapid Prototyping of Application Specific Signal Processors

To reduce manufacturing costs and assembly costs, Lockheed Martin Electronics and Missiles began developing concurrent engineering practices in late 1991. Because of the complexity of instant communication with the widespread vendors, Lockheed developed a direct communication tool called the Rapid Prototyping of Application Specific Signal Processors (RASSP) that is accessible through Internet (Figure 3-1). The pilot programs in this effort were Hellfire II and Longbow Missile, and produced manufacturing time reductions of 46.3% and 13.5%, respectively. RASSP maintains objectives to improve design quality by a concurrent design practice, and achieve a fourfold decrease in cycle time.

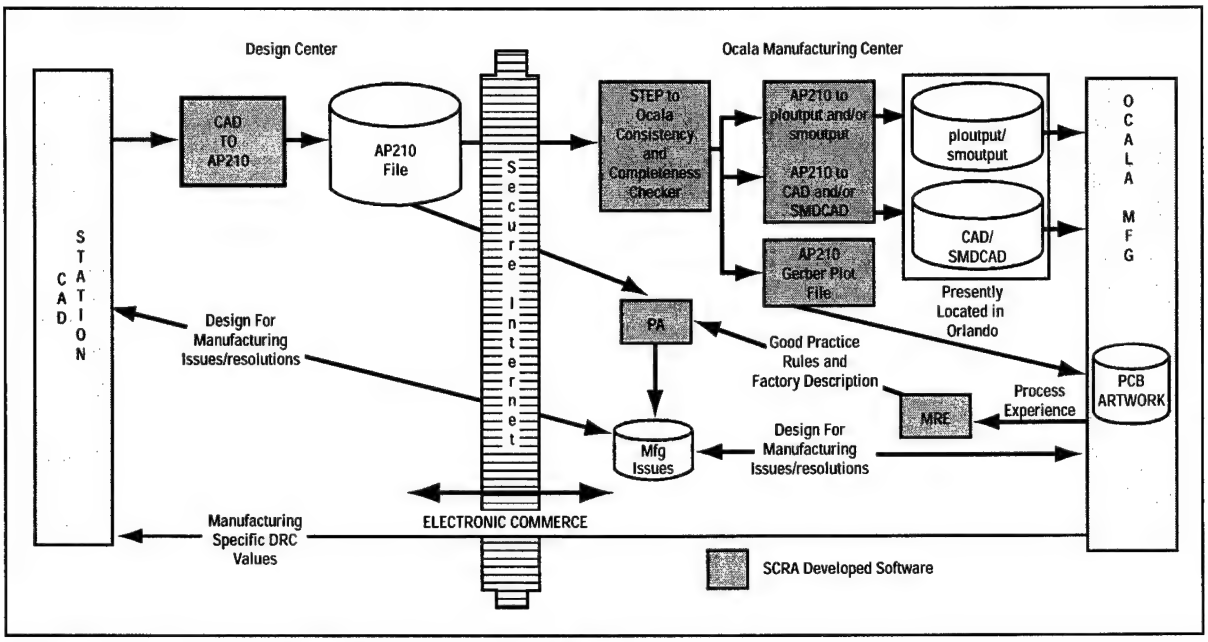


FIGURE 3-1. OCALA MANUFACTURING INTERNET CONNECTION TO THE CUSTOMER/VENDOR

In 1993, Lockheed Martin formed a RASSP team in partnership with approximately 20 other companies. The partnership will allow members to jointly develop software that each partner and its vendors can use to reduce cycle times and costs. The team is taking the following technical approach:

- integrating Incremental Refinement Methodology (users are involved early and often);
- using Modular Hardware and Software Architectures (scalable interconnects - Internet);
- developing Comprehensive Supporting Electronic Design Infrastructure (hardware and software reuse libraries);
- using Engineering Process Improvement Methodology including Concurrent Engineering, Design for Manufacture, Design for Assembly, and Design Cycle Reduction; and,
- applying unifying processes across all engineering disciplines (Design Review, Standard Engineering Processes and Tools, Standard Parts, Engineering/ AOD Interface, Central Engineering Services, Design Team Operation, Product Standardization, Design to Cost, Program Management, Requirements Management)

Development of RASSP, expected to be completed within two years, is anticipated to be an effective communication tool to benefit the industry in manufacturing cost savings.

QUALIFY MANUFACTURING PROCESS

Process Reengineering

Lockheed Martin is reengineering a number of processes within the company to move toward product-oriented and process-focused teams with equality of the functional organizations on the teams instead of the functional areas controlling the teams. These reengineering teams crosscut all functional organizations.

There has been a significant improvement in process cycle times and in cost reductions since the implementation of reengineering teams. For example, 1994 produced a cycle time improvement averaging 40% over six processes that underwent reengineering. The cost reduction averaged nearly 35%. This reengineering effort has been extended to Lockheed Martin and supplier interorganizational teams. The mutual problem-solving techniques are appreciated by the suppliers and subcontractors.

PIECE PART CONTROL

Southeast Material Acquisition Center

Lockheed Martin Electronics and Missiles maintains a Southeast Material Acquisition Center (SEMAC) to centralize purchasing areas in which maintaining an expert buyer base would provide substantial cost savings. This is a cost effective means of procurement from a centralized group

when specialized skills and knowledge are required to negotiate the best value. Benefits include an increased buyer knowledge of the marketplace; the best buyers are teamed with best suppliers; there is more intensive management to program procurements; staff has been reduced by up to 50%; redundancy in purchasing efforts is eliminated; buyer skills are improved and training of new buyers by experienced buyers can be accomplished; long-term forecasting and planning (leveraged buying) can be applied; company is positioned for electronic data interchange; and SEMAC helps Lockheed Martin remain competitive. Lockheed Martin achieved cost savings without reducing company competitiveness nor introducing delays in final product delivery.

The following functions are accomplished at the SEMAC:

- Purchasing
- Expediting
- Software Administration and Cataloging
- Liaison/Customer Service
- Source Technical Support
  - Engineering Support (Components, mechanical, material)
  - Software Licensing
- Small/Small Disadvantaged Business
- Compliance Management
- Supplier Interface
  - Supplier Performance and Measurement
  - Supplier Coding
  - Supplier Conferences
- Finance Support
  - Proposal Preparation
  - Cost Management
  - Evaluations
  - Savings

SUBCONTRACTOR CONTROL

Certified Supplier Program

Lockheed Martin developed a system of metrics to help achieve improved quality, cost competitive prices, and responsive suppliers. The company began implementing a quality rating system for suppliers in 1985 and followed up in 1989 with a more complete supplier performance system. The introduction in 1991 of a performance rating factor, which is quantitatively based on a supplier's past performance and product quality, produced a major reduction in procurement costs and aided in the process of reducing the number of suppliers (Figure 3-2).

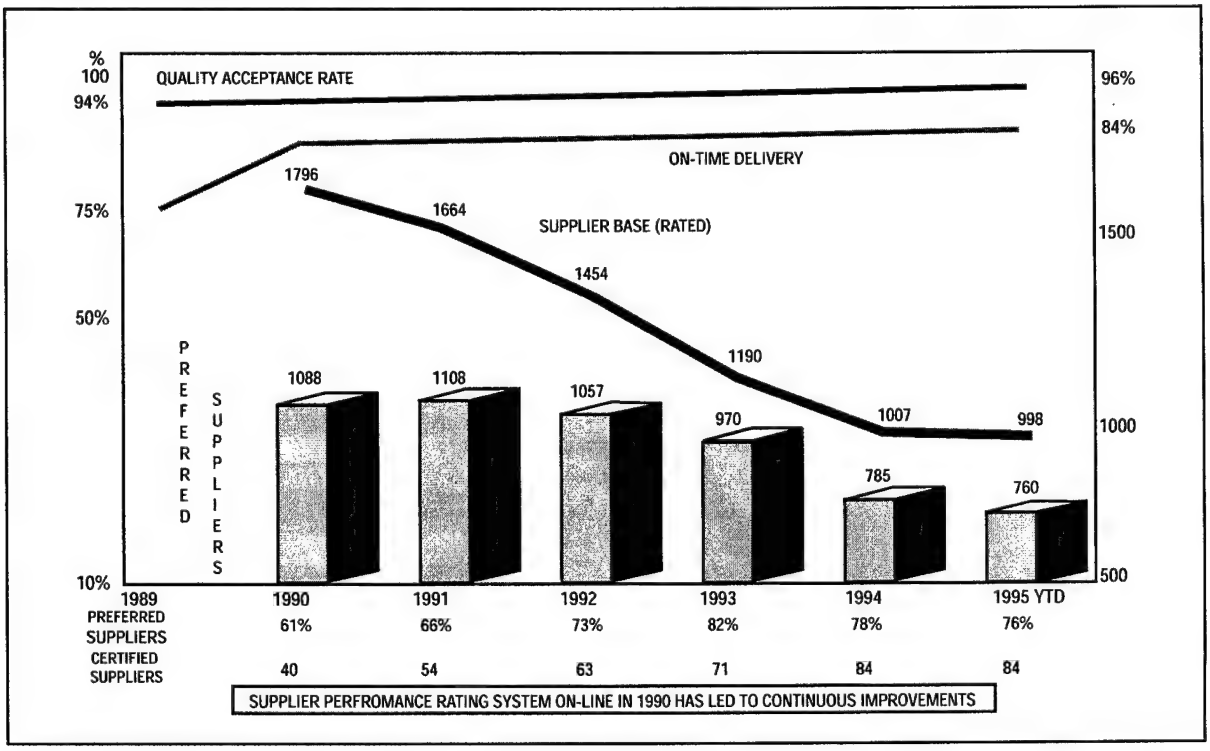


FIGURE 3-2. E&M SUPPLIER METRICS

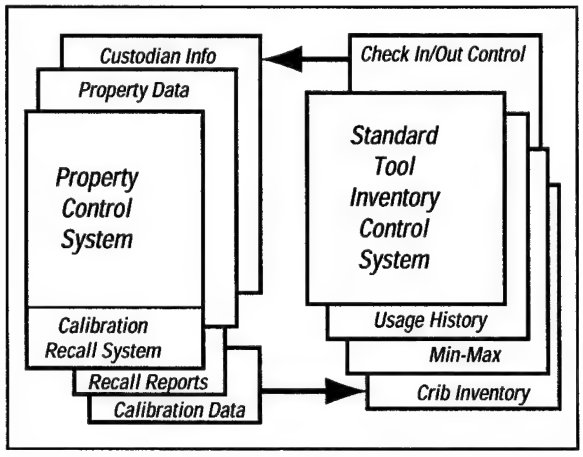


FIGURE 3-3. CALIBRATION RECALL CYCLE

The supplier rating criteria is based on scores from Quality Rating (100 points), On-Time Delivery (50 points), Scheduled Quantity (20 points), and Documentation (30 points). Out of the total of 200 points, a supplier must achieve a rating of 170 or better with a 99 point quality rating to be retained on a bidders list. Lower ratings cause an automatic lockout of that supplier. The improvement that has been achieved to date has been impressive.

TOOL PLANNING

Tool Calibration Recall System

Lockheed Martin Electronics and Missiles maintains a tool inventory of approximately 33,000 items, of which there are nearly 12,000 requiring some periodic calibration. To better ensure this process is completed on time and to ensure that no uncalibrated tools are on the shop floor, the company developed a highly effective and reliable computer monitoring system for tracking and recalling tools for recalibration (Figure 3-3). This system is critical to maintaining the requisite quality control for the precision shop work environment.

Since 1986, Lockheed Martin has linked the Property Control System with the Standard Tool Inventory Control System. This link controls tool checkout to a user who is personally responsible for its location, and from whom the equipment is recalled for calibration.

Some self-calibration is performed on items in the field. Also, some metrology stations are collocated in the critical shop areas to reduce the time a tool is out of service for recalibration. The virtual real-time nature of the tracking and control system, combined with a barcoded user/tool log-in process, has improved quality in the manufacturing process, and reduced the loss and abuse of tools in general.

PRODUCTION FABRICATION

Microelectronics Center

The Lockheed Martin Electronics and Missiles' Microelectronics Center (MEC) provides a diverse array of products, services and technical expertise. The MEC is a 100,000 square foot building housing design, development, manufacturing, and full military screening facilities for monolithic, hybrid, multi-chip modules, photoconductor, and P-I-N photodiode devices. Also housed in the MEC building is a complete failure analysis laboratory.

The MEC has produced over 1000 different types of custom microelectronics components and assemblies. It is facilitized to produce over 200,000 custom microelectronics devices annually in support of Lockheed Martin programs and external customers. The MEC is certified and qualified as a MIL-STD-1772 supplier by the Defense Electronic Supply Center per Qualified Manufactures List dated 17 July 1991. The MEC is also ISO 9001 registered.

MEC hybrid microcircuits incorporate both thick and thin film technologies. Ninety percent of MEC hybrids use thick film where tight tolerance performance is required. Thick-film hybrids are made by screen printing conductive inks onto ceramic substrates to form circuit patterns. As many as 20 layers are deposited and furnace-fired. Resistors are screened and discrete chip components are bonded onto the substrate and interconnected with gold wire. The hybrid package is sealed, leak-tested, and subjected to other environmental and functional tests. Hermetic chip carriers are surface-mounted integrated circuit packages that permit high-density populating of printed wiring boards. A number of basic sizes are used ranging from four to 64 pins. Some hermetic chip carriers packages are used for special hybrids or Large Scale Integration circuits.

Multi-chip modules are complex microcircuits with substrate densities ranging from 30% to 60%. These densities are required to maximize volumetric efficiency, minimize parasitic capacitance and inductance, decrease path lengths and in general control the impedance to a specific value. With system clock rates headed toward 100 MHz, the above criteria become crucial to circuit performance. Package sizes vary from three to ten square inches and component counts vary from 50 to 400. The active components range from interface ICs, to large area ASICs, to the state-of-the-art microprocessors. Input/output connections range from 90 to 500.

Custom semiconductor devices support in-house research and development engineering programs such as electro-optics, millimeter/GaAs, low observable strategic technologies; as well as production programs.

Facilities and technical expertise are available for the design and fabrication of semiconductor devices, on materials such as Si, GaAs, and HgCdTe, and thin film circuits on conventional and advanced ceramics such as AIN, SiC, and sapphire which are routinely processed for various programs.

The MEC's production areas are class 100,000 clean rooms. Detector wafer fabrication is class 1000, and the laminar flow booths are class 100. The facility conforms to MIL-M-38510 and produces components that meet test requirements of MIL-STD-883. The shop operates under a product assurance program compliant to MIL-Q-9858.

The MEC provides impressive failure analysis services. The laboratory has extensive capabilities including real-time X-ray Analysis, Scanning Electron Microscopy, Acoustic Microscopy, Surface Analysis, Infrared Spectroscopy, Constructional Analysis, Nondestructive Analysis, Thermal Imaging/Analysis, Electrical Characterization, Environmental Tests, Dimensional Analysis, and Material Analysis.

3.4 FACILITIES

MODERNIZATION

Production Line Strategies

The Lockheed Martin Electronics and Missiles plant at Ocala, FL contains a state-of-the-art PWB/PWA manufacturing facility encompassing 116,620 square feet. Compliance/certification of the facility includes an ISO 9001 quality system, MIL-Q-9858 quality program, MIL-S-45743 high reliability soldering, MIL-S-46844 machine soldering, MIL-P-46843 PWA workmanship, MIL-STD-2000A solder and assembly workmanship, and a MIL-STD-45662 calibration system. The facility also has a complete cable and harness manufacturing area with a demonstrated capacity of 2500 items per week on a 1-8-5 operation.

This unique facility applies not only broad-based assembly process techniques, but is flexible enough to be either product-arranged or commodity-arranged. The production lines can easily be changed to become customer-oriented (product), or process-oriented (process). Leaded component PWA and surface mount technology PWA capabilities are also housed at this facility.

The Lockheed Martin, Ocala facility has been designated a Center Of Excellence for PWAs for all Lockheed Martin companies and will be the primary supplier of PWAs to the corporation. The business base will be approximately 40% Electronics and Missiles, 40% other Lockheed Martin Corporation business, and 20% commercial business.

FACTORY IMPROVEMENTS

Rapid Prototyping

Lockheed Martin Electronics and Missiles uses a stereolithography apparatus (SLA) system in its rapid prototyping efforts. The company maintains both SLA 250 and SLA 500 devices. Manufacturing of models by the SLA process allows for quick turnaround of a hard copy from engineering three-dimensional databases. The SLA process eliminates costly tooling and machining processes and allows for early design reviews of new products or proof-out of product concepts. With the use of SLA models, an engineer can easily improve the product design by going through more iterations before committing the design to production. Some of the additional benefits of this process are reduced design errors, more producible parts, assembly validation, numerical control program validation, rapid acquisition of castings, and improved communication between engineering, manufacturing, vendors, and customers.

Because today's business environment requires production companies to increasingly shorten their product design and development times and to shorten their overall time to market for new products, Lockheed Martin is successfully applying SLA to its quick turnaround manufacturing processes.

3.5 MANAGEMENT

MANUFACTURING STRATEGY

Risk Management

Risk Management is one of 12 Lockheed Martin-developed Best Practice activities for continuous improvement. Risk Management identifies, assesses, and abates factors which could reasonably result in not attaining cost, performance, or schedule. The company believes that by applying risk management techniques, up-front planning and programmatic trade-offs can be planned to ensure executable programs. Also, the program technical, schedule, and cost issues can be integrated, and quick reaction capability to "what ifs" can be provided to minimize programmatic surprises.

The risk management process has been developed for the Integrated Product Teams to identify high risk areas early enough to resolve. Old risk management practices employed by Lockheed Martin separated schedules, events, and issues instead of integrating with each other, resulting in a less-than-adequate analysis of the risk involved when planning a program. Refining this risk management process, Lockheed Martin assembled its

ability to integrate systems, the attributes of the already existing risk management techniques, and the Defense System Management College tools for risk management. The resultant tool is an integrated risk management tool based on relationships and effects of each aspect of a program. The tool enables a standard approach to risk analysis, tracking, and reporting.

The newly refined integrated risk management process is currently in its final stages of implementation and has not yet established a track record. However, there are early indications of an improved and cost effective process as a result of Lockheed Martin's continuous improvement efforts.

Partnerships

Lockheed Martin Electronics and Missiles has developed partnerships with state and local governments, industry, academia, and federal government industrial activities to support its Ocala operations initiatives. Lockheed Martin management has taken a progressive approach to further its business opportunities by developing cooperative relationships outside the organization. Partnerships have been established with state and local governments of the City of Ocala, Marion County, and the State of Florida; industry partners include suppliers and industries competent in the technical areas of astro-space, information systems, and electronics, and academia partners such as Central Florida Community College and Lakewood High School.

Examples of partnerships benefiting the business strategies of Lockheed Martin include the following examples.

- The City of Ocala funded a five-year lease of a facility for housing the Lockheed Martin Ocala Operations in return for a guarantee of 100 jobs created by the Ocala operations.
- The State of Florida funded a training program to enable area personnel resources to qualify for Ocala Operations jobs.
- Marion County shared the cost with Ocala Operations to design and install a waste water recovery system.
- Selected industry partners exchanged their technical expertise and production experience with Ocala Operations to continuously improve the technology base.
- Suppliers are considered partners as soon as they are awarded a contract. Technology know-how and mission plans are passed on to the suppliers, and the suppliers participate in Ocala Operation's process/product improvement activities such as providing feedback into new designs.

Many of the business opportunities enjoyed by the Ocala Operations in the areas of new markets, personnel resources, facilities, design technology, fabrication methodology, and test have been made possible through Lockheed Martin Partnerships with state and local government, industry, and academia.

New Business Development

Lockheed Martin Electronics and Missiles, Ocala operations has been a captive supplier of PWBs, CCAs, cables and harnesses, power supplies and precision electromechanical assemblies to Martin Marietta's Electronics and Missiles Company for 24 years. However, as the result of Department of Defense budget reductions and the resulting decrease in the number and size of production contracts, Ocala has revised its business strategy to reduce its dependence on E&M programs by expanding and diversifying its business base. This strategy entails a three-phased plan which calls for penetration of other Lockheed Martin operations, government programs outside of the Department of Defense, and entering the outside commercial market. Achieving these goals will reduce the variability associated with the exclusive E&M and Department of Defense programs and increase the base, allowing greater absorption of fixed costs and consequently, making Ocala operations more affordable.

To carry out this plan, Ocala has created a new business development organization with a charter to develop and achieve a 5-year strategic plan that is disciplined and focused. This strategic plan integrates all initiatives across all functions and programs. The plan leverages Ocala's key competencies including its ability to deliver quality products on schedule and at low cost, its core technologies and capabilities, flexible and agile manufacturing capabilities, favorable labor relationships, investment from local, state and federal agencies, and strategic partnerships with customers and suppliers. All of these competencies are monitored by management under the umbrella of Lockheed Martin Electronics and Missiles'12 Best Practices program that measures continuous improvement and migration of commercial practices, as regulations and programs permit.

Customer Focus and Feedback

Customer focus and feedback is one of the twelve Best Practices focus areas at Lockheed Martin Electronics and Missiles. The objectives of customer focus are to improve the customer feedback loop, involve customers as team members, enhance Lockheed Martin's image as a valued producer, and foster continuous improvement.

Some customer expectations are constant, including producing the best quality product for the dollars expended, optimizing performance, delivering on time, reliability, and supportability. However, the environment is one of constant

change with new program starts on the decline and many major systems being canceled. Affordability and cost of ownership are major drivers and multi-user weapon systems and platforms are becoming the norm. To adapt and survive in this changing environment, Lockheed Martin wants to become involved with customers early and stay involved. The major initiative for Lockheed Martin in 1995 is to develop effective mechanisms for teaming with the customer. Two key elements of this effort are customer IPT membership and contract performance feedback.

Including customers as members of IPTs has been the single most effective method of achieving total customer involvement. It has brought down many of the barriers and cost drivers that traditionally inhibit success in acquisition programs. Involvement of customers at this level effectively eliminates the need for many reviews, quality inspections, approvals, and other bureaucratic requirements that add little value but drive cost and schedule dramatically. The concept is being piloted in several company programs.

Lockheed Martin has implemented a number of effective methods for customer feedback. Formal feedback mechanisms such as checklists and the Air Force's Contractor Performance Assessment Report are used. Program personnel work with customer representatives in each major area of a program to prepare a pre-Contractor Performance Assessment Report to avoid unexpected events. Results are collected in a central repository for each program. Each Program Manager prepares a customer assessment report form each month and reports to the mission area vice-president. Each mission area vice-president prepares a customer assessment report on each product quarterly and reports to the company president. Customer assessments are included in each program review. IPT leaders meet at least weekly with customer counterparts, and program managers meet at least monthly with theirs. Customer assessment reports are prepared based on these meetings and action plans are initiated.

These initiatives have resulted in outstanding customer interface for Lockheed Martin Electronics and Missiles' programs. Potential issues are identified and addressed early, enabling a focus on best value and mission success.

Supplier Partnerships

Lockheed Martin Electronics and Missiles considers supplier partnerships and related practices as critical to winning new business. Within this arena, there are a number of active initiatives and thrusts including strategic alliances, teaming with suppliers, supplier membership on Integrated Product Teams, Design for Manufacturability/Assembly flowdown to suppliers, SPC/Variability Reduction flowdown, expanding the blanket purchase and group purchase base, supplier base reductions, supplier metrics, and best value awards.

Partnerships foster joint commitments between companies and promote shared investments which focus internal research and development activities and result in ownership of products. Partners take mutual ownership of problems and solutions, and apply their complementary strengths to address weaknesses.

Lockheed Martin is rapidly moving from the traditional adversarial approach to subcontracting. This new approach to supplier partnerships is based on sharing, defining clear expectations, mutual trust and respect, commitment, responsibility, and performance. Partnerships are initiated by selecting the best technology or product available and entering into a teaming agreement with the provider. Communication is open, full, and sensitive data is shared. To encourage such communication, E&M employs confidentiality agreements that are skewed in favor of protecting the discloser's technology versus limiting the receiver's liability.

The key elements of a partnership:

SHARING	• Long-term strategies and marketing plans • Understand mutual goals/objectives • Proportionately share risk and benefits • Coordinate IRAD
CLEAR EXPECTATIONS	• Define mutual win/win strategies, minimal development • Partner's pricing is reasonable and represents best overall value and must be demonstrated with each new procurement action
TRUST/RESPECT	• Inform partner when other partners exist as potential competitors • Candidly discuss the role of the partner in development and production which may differ or disappear • Full and open communications
COMMITMENT	• Continuous improvement • Restrict initial solicitation to partner
RESPONSIBILITY	• Be accountable and up front with partners • Publicize identification of partner through Corporation
PERFORMANCE	• Expect excellence and give excellence in return

The company is committed to partnering and has mandated this approach for all future starts. The philosophy is also being applied to mature programs where possible.

Partnerships and alliances are a key part of the procurement process and are integrated early. Subcontractors are involved in the market analysis, pre-proposal, and proposal phases. They participate in life-of-the-program decisions, requirements specifications, design for manufacturing and assembly, manufacturing development initiatives, and concurrent engineering. Benefits of this involvement include long term contracts, design-to-unit cost pricing, mutual commitments to program goals, and utilization of commercial standards.

All supplier initiatives at Lockheed Martin Electronics and Missiles form an integrated process that result in best value and mission success (Figure 3-4). Unique involvement activities include Partners in Excellence Conferences, General Managers Meetings, and supplier membership on IPTs. Supplier membership on IPTs has been implemented successfully on two major programs and is mandated for all new programs. Benefits of IPT involvement include transferring build-to-print design responsibility to subcontractors with resultant savings; co-development of proposals, designs, test equipment, manufacturing tooling and processes; sharing the cost of key process development; and other cost reduction activities such as design for manufacturing and assembly which reduced the cost of an existing assembly by over 70% on one program.

Process Oriented Contract Administration Services

Process Oriented Contract Administration Services (PROCAS) is a process-oriented approach to contract administrative services, and establishes a method for continuous verifiable improvements to help ensure successful completion of contracts. This effort involves joint government-industry participation and cooperation and has been extremely effective at Lockheed Martin Electronics and Missiles. Processes at Lockheed Martin and similar ones by the Defense Logistic Agency DPRO combined to produce an effective PROCAS process (Figure 3-5). The mission statement was to improve and control processes to ultimately provide high quality products and services to their mutual customer.

PROCAS provides an excellent example of a cooperative work team that has not only streamlined processes, but has also built trust. One reason behind the PROCAS success is DPRO's identification of critical processes for managing contracts, and the Lockheed Martin identification of critical processes for managing business. Lockheed Martin applied a Quality Function Deployment methodology to work through many of the complicated issues, including the selection process of what the PROCAS team should address

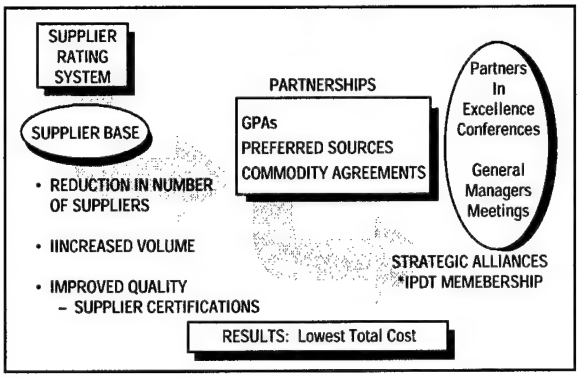


FIGURE 3-4. PARTNERSHIP / ALLIANCE PROCESS

and in what priority. Both DPRO and Lockheed Martin personnel believe the PROCAS method is working to improve and strengthen the contracting and verification process.

Process Simplification – A Total Quality Concept

Process Simplification (PROSIM) is part of Lockheed Martin Electronics and Missiles' total quality movement. PROSIM involves the employees in a systematic approach to problem solving and was the precursor to Lockheed Martin's reengineering program. The PROSIM methodology makes use of teams to develop change processes for typically multifunctional areas. The model used for this process improvement makes use of the five "I's" – inspiration, initiation, investigation, innovation, and implementation. This method is similar to many companies' process flows through their TQM departments.

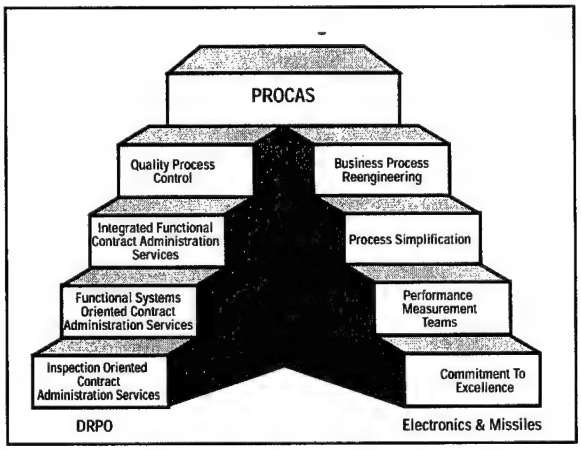


FIGURE 3-5. MERGING OF CULTURES (PROCAS)

During the investigation and innovation phase, an as-is flow chart is developed of a unit's process. This is followed by a team meeting to develop a should-be flow process. Obtaining senior management approval to change the as-is to the should-be has been supported by Lockheed Martin senior management. A computer simulation has been used to work the "what if" process changes to explore the management space thoroughly. A set of charts is developed that reflect the PROSIM team's objectives, measurable results, accomplishments to date, the process flows, and a list of action items and personal accountabilities. Members of a PROSIM team share in the savings/cost avoidance resulting from the company receives due to the implementation of the team's recommendations.

Management Control Process

Lockheed Martin Electronics and Missiles' Ocala operation has developed and adopted a wide range of management practices in support of its mission statement. That statement includes application of low cost manufacturing, world class quality, and proven technologies to the development, production, and management of electronic commodities for the Lockheed Martin Corporation and outside markets. The management control process is the means by which Ocala has integrated the output of its variety of management reporting systems for senior management monitoring.

The Lockheed Martin Ocala management control process is comprised of six discrete mechanisms. Corrective Action Boards focus on program issues and are chaired by program managers. Meetings are held weekly where the goal is to identify root causes and to make the transition from corrective action to preventive action. The Senior Performance Management Teams meet monthly, primarily to ensure consistent implementation of corporate objectives. Issues such as performance-to-standard, yield improvement and delivery-to-schedule are addressed. Schedule status committees meet weekly to discuss issues such as procurement status, systems delivery status and component and subassembly build status. Red-Yellow-Green By Program meetings are held bi-weekly. Using the colors of red, yellow, and green to indicate the severity of a particular issue, discussions are held concerning quality, schedule performance, procurement status, cost performance and technical issues. The Change Board meets weekly to ensure all design and process changes are implemented. Finance reviews are held weekly and monthly to discuss actual hours per unit versus planned hours per unit, overtime utilization, earned value, and the support ratio.

The Lockheed Martin Ocala management control process integrates a variety of management reporting systems and provides senior management with the means to monitor activities and contribute to continuous improvement and a quality product.

ISO 9001 Certification Process

Lockheed Martin Electronics and Missiles assembled a multi-disciplined, multifunctional working committee to plan and take the required actions toward ISO 9001 certification. One of the first steps was the selection of the accreditation board/registrar. BSI-QA was selected because of the world-wide acceptance of the certification, and BSI-QA was accredited to certify companies for missiles by the NACCB.

A milestone plan was developed for the process to ensure that the certification process was on track. A Quality Systems Manual was developed to include the compilation of all current procedures, and the system was purged of unnecessary procedures. Training was considered to be one of the most important facets to the implementation. Seven lead assessors were trained through a five-day course, and 33 internal auditors from different functional areas completed the three day, in-house training. A video was shown and presentations were made to all hands.

The pre-assessment audit was performed by BSI-QA in July 1994. No systemic issues were found, but the internal audit system needed upgrading and a quality policy flowdown was required. A quality system audit program was instituted using the lead assessors and internal auditors. The assessment audit was conducted by BSI-QA in November 1994, with no systemic issues found, and certification was recommended. The corrective/preventive action plan was submitted in December 1994, and certification was received in mid-December 1994.

The planning and methodology used for achieving the certification was the key to being able to complete the process in the short time period targeted.

Production Process Verification

The Production Process Verification (PPV) system recently instituted at Lockheed Martin Electronics and Missiles has provided significant improvements in the areas of quality and first time yields in products manufactured at that facility. Lockheed Martin defines PPV as "a quality surveillance system which vests responsibility for product quality with those who build the product."

In developing and implementing the new process, individual work teams were established to train and build quality into the product and take responsibility for proactive defect prevention. Process operators were trained to ensure they had the skill and knowledge necessary to assume sole responsibility for the quality of products that they produced. Specific operators were certified for manufacture of specific hardware and processes were certified. Operators were then trained to

the concept of process certification. The teams were then instructed in how to establish and maintain metrics to help to monitor their progress. The traditional product inspectors became quality assurance personnel who monitored the process and not the work of the operators. These quality assurance personnel became key personnel in helping the process operators maintain the production process and build quality into the product.

Prior to implementation of this process, the company commonly saw first time yields of 85%, rework of product of 3.0%, and total product manufacturing cycle times of 19 days. Once the process became robust, first time yields rose to 98%, rework dropped to 0.5%, and total manufacturing span time dropped to 15 days.

APPENDIX A

TABLE OF ACRONYMS

ACRONYM	DEFINITION
APECS	Aerospace Planning Execution Control System
BMP	Best Manufacturing Practices
BOM	Bill of Material
CEM	Concurrent Engineering Manager
$(CP)^2$	Contractor Performance Certification Program
DOD	Department of Defense
DFMA	Design for Manufacture/Assembly
E&M	Electronics and Missiles
FACTS	Factory Control and Tracking System
IPPD	Integrated Product/Process Development
IPT	Integrated Product Team
MDP	Metric Development Process
MEC	Microelectronics Center
MP	Manufacturing Process
MRS	Manufacturing Reporting System
PCS	Property Control System
PDS	Product Definition System
PM	Product Manager
PMT	Performance Management Team
PPV	Production Process Verification
PROCAS	Process Oriented Contract Administration Services
PROSIM	Process Simplification
RASSP	Rapid Prototyping of Application Specific Signal Processors
RAPID	Routing and Process Instruction Development
SEMAC	Southeast Material Acquisition Center
SLA	Stereolithography Apparatus
SMART	Simplified Material and Requirements Tracking
TQM	Total Quality Management

APPENDIX B

BMP SURVEY TEAM

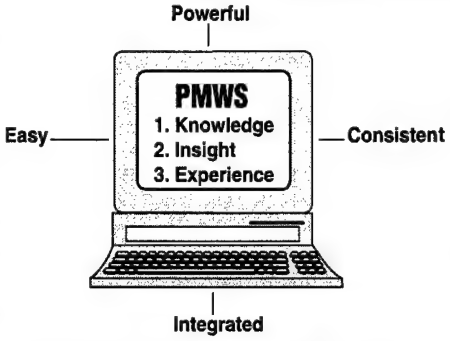
TEAM MEMBER	ACTIVITY	FUNCTION
Larry Robertson (812) 854-5336	**Crane Division** **Naval Surface Warfare Center** Crane, IN	**Team Chairman**
Amy Scanlan (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Technical Writer**
	Design/Test Team	
Dave Kuchler (317) 306-7961	**Naval Air Warfare Center** **Aircraft Division - Indianapolis** Indianapolis, IN	**Team Leader**
Jeff Parks (810) 574-5558	**U.S. Army Tank Automotive Command** Warren, MI	
	Production/Facilities Team	
Don Hill (317) 306-3781	**Naval Air Warfare Center** **Aircraft Division - Indianapolis** Indianapolis, IN	**Team Leader**
Satya Duvvuri (909) 273-5424	**Naval Warfare Assessment Division** Corona, CA	
	Management/Logistics Team #1	
Larry Halbig (317) 306-3838	**Naval Air Warfare Center** **Aircraft Division - Indianapolis** Indianapolis, IN	**Team Leader**
Jamie Slattery (603) 954-3296	**Industry Canada** **Marine & Land Defence** **Systems Directorate** Ottawa, Ontario	
	Management/Logistics Team #2	
Rick Purcell (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Team Leader**
Alan Mense (301) 403-8100	**BMP Center of Excellence** College Park, MD	

APPENDIX C

PROGRAM MANAGER'S WORKSTATION

The Program Manager's Workstation (PMWS) is a series of expert systems that provides the user with knowledge, insight, and experience on how to manage a program, address technical risk management, and find solutions that industry leaders are using to reduce technical risk and improve quality and productivity. This system is divided into four main components; KNOW-HOW, Technical Risk Identification and Mitigation System (TRIMS), BMP Database, and Best Manufacturing Practices Network (BMPnet).

- **KNOW-HOW** is an intelligent, automated method that turns "Handbooks" into expert systems, or digitized text. It provides rapid access to information in existing handbooks including Acquisition Streamlining, Non-Development Items, Value Engineering, NAVSO P-6071 (Best Practices Manual), MIL-STD-2167/2168, SecNav 5000.2A and the DoD 5000 series documents.



PROGRAM MANAGER'S WORKSTATION

- **TRIMS** is based on DoD 4245.7-M (the transition templates), NAVSO P-6071 and DoD 5000 event oriented acquisition. It identifies and ranks the high risk areas in a program. TRIMS conducts a full range of risk assessments throughout the acquisition process so corrective action can be initiated before risks develop into problems. It also tracks key project documentation from concept through production including goals, responsible personnel, and next action dates for future activities in the development and acquisition process.

- The **BMP Database** draws information from industry, government, and the academic communities to include documented and proven best practices in design, test, production, facilities, management, and logistics. Each practice in the database has been observed and verified by a team of experienced government engineers. All information gathered from BMP surveys is included in the BMP Database, including this survey report.

- **BMPnet** provides communication between all PMWS users. Features include downloading of all programs, E-mail, file transfer, help "lines", Special Interest Groups (SIGs), electronic conference rooms and much more. Through BMPnet, IBM or compatible PC's and Macintosh computers can run all PMWS programs.

- To access **BMPnet** efficiently, users need a special modem program. This program can be obtained by calling the BMPnet using a VT-100/200 terminal emulator set to 8,N,1. Dial (703) 538-7697 for 2400 baud modems and (703) 538-7267 for 9600 baud and 14.4 kb. When asked for a user profile, type: DOWNPC or DOWNMAC <return> as appropriate. This will automatically start the Download of our special modem program. You can then call back using this program and access all BMPnet functions. The General User account is:

  USER PROFILE: BMPNET

  USER I.D.: BMP

  Password: BMPNET

If you desire your own personal account (so that you may receive E-Mail), just E-Mail a request to either Ernie Renner (BMP Director) or Brian Willoughby (CSC Program Manager). If you encounter problems please call (703) 538-7253.

APPENDIX D

NAVY CENTERS OF EXCELLENCE

Automated Manufacturing Research Facility
(301) 975-3414

The Automated Manufacturing Research Facility (AMRF) – a National Center of Excellence – is a research test bed at the National Institute of Standards and Technology located in Gaithersburg, Maryland. The AMRF produces technical results and transfers them to the Navy and industry to solve problems of automated manufacturing. The AMRF supports the technical work required for developing industry standards for automated manufacturing. It is a common ground where industry, academia, and government work together to address pressing national needs for increased quality, greater flexibility, reduced costs, and shorter manufacturing cycle times. These needs drive the adoption of new computer-integrated manufacturing technology in both civilian and defense sectors. The AMRF is meeting the challenge of integrating these technologies into practical, working manufacturing systems.

Electronics Manufacturing Productivity Facility
(317) 226-5607

Located in Indianapolis, Indiana, the Electronics Manufacturing Productivity Facility (EMPF) is a National Center of Excellence established to advance state-of-the-art electronics and to increase productivity in electronics manufacturing. The EMPF works with industry, academia, and government to identify, develop, transfer, and implement innovative electronics manufacturing technologies, processes, and practices. The EMPF conducts applied research, development, and proof-of-concept electronics manufacturing and design technologies, processes, and practices. It also seeks to improve education and training curricula, instruction, and necessary delivery methods. In addition, the EMPF is striving to identify, implement, and promote new electronics manufacturing technologies, processes, materials, and practices that will eliminate or reduce damage to the environment.

National Center for Excellence in Metalworking Technology
(814) 269-2420

The National Center for Excellence in Metalworking Technology (NCEMT) is located in Johnstown, Pennsylvania and is operated by Concurrent Technologies Corporation (CTC), a subsidiary of the University of Pittsburgh Trust. In support of the NCEMT mission, CTC's primary focus includes working with government and industry to develop improved manufacturing technologies including advanced methods, materials, and processes, and transferring those technologies into industrial applications. CTC maintains capabilities in discrete part design, computerized process analysis and modeling, environmentally compliant manufacturing processes, and the application of advanced information science technologies to product and process integration.

Center of Excellence for Composites Manufacturing Technology
(414) 947-8900

The Center of Excellence for Composites Manufacturing Technology (CECMT), a national resource, is located in Kenosha, Wisconsin. Established as a cooperative effort between government and industry to develop and disseminate this technology, CECMT ensures that robust processes and products using new composites are available to manufacturers. CECMT is operated by the Great Lakes Composites Consortium. It represents a collaborative approach to provide effective advanced composites technology that can be introduced into industrial processes in a timely manner. Fostering manufacturing capabilities for composites manufacturing will enable the U.S. to achieve worldwide prominence in this critical technology.

Navy Joining Center
(614) 486-9423

The Navy Joining Center (NJC) is a Center of Excellence established to provide a national resource for the development of materials joining expertise, deployment of emerging manufacturing technologies, and dissemination of information to Navy contractors, subcontractors, Navy activities, and U.S. industry.

The NJC is located in Columbus, Ohio, and is operated by Edison Welding Institute (EWI), the nation's largest industrial consortium dedicated to materials joining. The NJC combines these resources with an assortment of facilities and demonstrated capabilities from a team of industrial and academic partners. NJC technical activities are divided into three categories - Technology Development, Technology Deployment, and Technology Transfer. Technology Development maintains a goal to complete development quickly to initiate deployment activities in a timely manner. Technology Deployment includes projects for rapid deployment teaming and commercialization of specific technologies. The Technology Transfer department works to disseminate pertinent information on past and current joining technologies both at and above the shop floor.

APPENDIX E

NEW BEST MANUFACTURING PRACTICES PROGRAM TEMPLATES

Since 1985, the BMP Program has applied the templates philosophy with well-documented benefits. Aside from the value of the templates, the templates methodology has proven successful in presenting and organizing technical information. Therefore, the BMP program is continuing this existing "knowledge" base by developing 17 new templates that complement the existing DoD 4245.7-M or Transition from Design to Production templates.

The development of these new templates was based in part on Defense Science Board studies that have identified new technologies and processes that have proven successful in the last few years. Increased benefits could be realized if these activities were made subsets of the existing, compatible templates.

Also, the BMP Survey teams have become experienced in classifying Best Practices and in technology transfer. The Survey team members, experts in each of their individual fields, determined that data collected, while related to one or more template areas, was not entirely applicable. Therefore, if additional categories were available for Best Practices "mapping," technology transfer would be enhanced.

Finally, users of the Technical Risk Identification and Mitigation System (TRIMS) found that the program performed extremely well in tracking most key program documentation. However, additional categories – or templates – would allow the system to track all key documentation.

Based on the above identified areas, a core group of activities was identified and added to the "templates baseline." In addition, TRIMS was modified to allow individual users to add an unlimited number of user-specific categories, templates, and knowledge-based questions.

APPENDIX F

COMPLETED SURVEYS

BMP surveys have been conducted at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPNET. Requests for copies of recent survey reports or inquiries regarding the BMPNET may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 308
College Park, MD 20740
Attn: Mr. Ernie Renner, Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
ernie@bmpcoe.org

COMPANIES SURVEYED

Litton
Guidance & Control Systems Division
Woodland Hills, CA
October 1985 and February 1991

Texas Instruments
Defense Systems & Electronics Group
Lewisville, TX
May 1986 and November 1991

Harris Corporation
Government Support Systems Division
Syosset, NY
September 1986

Control Data Corporation
Government Systems Division
(Computing Devices International)
Minneapolis, MN
December 1986 and October 1992

ITT
Avionics Division
Clifton, NJ
September 1987

UNISYS
Computer Systems Division
(Paramax)
St. Paul, MN
November 1987

Honeywell, Incorporated
Undersea Systems Division
(Alliant Tech Systems, Inc.)
Hopkins, MN
January 1986

General Dynamics
Pomona Division
Pomona, CA
August 1986

IBM Corporation
Federal Systems Division
Owego, NY
October 1986

Hughes Aircraft Company
Radar Systems Group
Los Angeles, CA
January 1987

Rockwell International Corporation
Collins Defense Communications
(Rockwell Defense Electronics
Collins Avionics and
Communications Division)
October 1987 and March 1995

Motorola
Government Electronics Group
Scottsdale, AZ
March 1988

General Dynamics
Fort Worth Division
Fort Worth, TX
May 1988

Hughes Aircraft Company
Missile Systems Group
Tucson, AZ
August 1988

Litton
Data Systems Division
Van Nuys, CA
October 1988

McDonnell-Douglas Corporation
McDonnell Aircraft Company
St. Louis, MO
January 1989

Litton
Applied Technology Division
San Jose, CA
April 1989

Standard Industries
LaMirada, CA
June 1989

Teledyne Industries Incorporated
Electronics Division
Newbury Park, CA
July 1989

Lockheed Corporation
Missile Systems Division
Sunnyvale, CA
August 1989

General Electric
Naval & Drive Turbine Systems
Fitchburg, MA
October 1989

TRICOR Systems, Incorporated
Elgin, IL
November 1989

TRW
Military Electronics and Avionics Division
San Diego, CA
March 1990

Texas Instruments
Defense Systems & Electronics Group
Dallas, TX
June 1988

Bell Helicopter
Textron, Inc.
Fort Worth, TX
October 1988

GTE
C^3 Systems Sector
Needham Heights, MA
November 1988

Northrop Corporation
Aircraft Division
Hawthorne, CA
March 1989

Litton
Amecom Division
College Park, MD
June 1989

Engineered Circuit Research, Incorporated
Milpitas, CA
July 1989

Lockheed Aeronautical Systems Company
Marietta, GA
August 1989

Westinghouse
Electronic Systems Group
Baltimore, MD
September 1989

Rockwell International Corporation
Autonetics Electronics Systems
Anaheim, CA
November 1989

Hughes Aircraft Company
Ground Systems Group
Fullerton, CA
January 1990

MechTronics of Arizona, Inc.
Phoenix, AZ
April 1990

Boeing Aerospace & Electronics
Corinth, TX
May 1990

Textron Lycoming
Stratford, CT
November 1990

Naval Avionics Center
Indianapolis, IN
June 1991

Kurt Manufacturing Co.
Minneapolis, MN
July 1991

Raytheon Missile Systems Division
Andover, MA
August 1991

Tandem Computers
Cupertino, CA
January 1992

Conax Florida Corporation
St. Petersburg, FL
May 1992

Hewlett-Packard
Palo Alto Fabrication Center
Palo Alto, CA
June 1992

Digital Equipment Company
Enclosures Business
Westfield, MA and
Maynard, MA
August 1992

NASA Marshall Space Flight Center
Huntsville, AL
January 1993

Department of Energy-
Oak Ridge Facilities
Operated by Martin Marietta Energy Systems, Inc.
Oak Ridge, TN
March 1993

Technology Matrix Consortium
Traverse City, MI
August 1990

Norden Systems, Inc.
Norwalk, CT
May 1991

United Electric Controls
Watertown, MA
June 1991

MagneTek Defense Systems
Anaheim, CA
August 1991

AT&T Federal Systems Advanced
Technologies and AT&T Bell Laboratories
Greensboro, NC and Whippany, NJ
September 1991

Charleston Naval Shipyard
Charleston, SC
April 1992

Texas Instruments
Semiconductor Group
Military Products
Midland, TX
June 1992

Watervliet U.S. Army Arsenal
Watervliet, NY
July 1992

Naval Aviation Depot
Naval Air Station
Pensacola, FL
November 1992

Naval Aviation Depot
Naval Air Station
Jacksonville, FL
March 1993

McDonnell Douglas Aerospace
Huntington Beach, CA
April 1993

Crane Division
Naval Surface Warfare Center
Crane, IN and Louisville, KY
May 1993

R. J. Reynolds Tobacco Company
Winston-Salem, NC
July 1993

Hamilton Standard
Electronic Manufacturing Facility
Farmington, CT
October 1993

Harris Semiconductor
Melbourne, FL
January 1994

Naval Undersea Warfare Center
Division Keyport
Keyport, WA
May 1994

Kaiser Electronics
San Jose, CA
July 1994

Stafford County Public Schools
Stafford County, VA
July 1994

Lockheed Martin
Electronics & Missiles
Orlando, FL
April 1995

Philadelphia Naval Shipyard
Philadelphia, PA
June 1993

Crystal Gateway Marriott Hotel
Arlington, VA
August 1993

Alpha Industries, Inc
Methuen, MA
November 1993

United Defense, L.P.
Ground Systems Division
San Jose, CA
March 1994

Mason & Hanger
Silas Mason Co., Inc.
Middletown, IA
July 1994

U.S. Army
Combat Systems Test Activity
Aberdeen, MD
August 1994

Sandia National Laboratories
Albuquerque, NM
January 1995

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F. The foregoing information was compiled and provided by:
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